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REAR-ADMIRAL THORNTON A. JENKINS, U. S. N., in the Chair.

SMITH SOUND AND ITS EXPLORATION.

BY DR. EMIL BESSELS.

A body of water of striking peculiarity separates Greenland from the American continent and its ice-bound archipelago extending towards the Pole. It's length of 1300 miles is equalled only by that of the Red Sea. Fully 600 miles wide at its southern entrance, with an average depth of 1500 fathoms between Cape Farewell and the northeastern extremity of Labrador, it gradually narrows towards the Arctic circle, having, however, between its bleak shores of metamorphic rock a width of not less than 150 miles. Thence it widens as far as Cape York. Narrowing again north of Jones Sound, the two coasts approach each other so closely beyond Cape Isabella and Cape Alexander, that one might be tempted to try sending a rifle-ball from the Greenland side to the opposite coast, with its steep mountain peaks, set off from their dark background by glittering glaciers.

This is Smith Sound, the discovery of which dates back to the early part of the seventeenth century. The treasures of India, which gave the incentive to attempts to find the northern passages, induced also a number of English noblemen and commercial adventurers to equip an expedition for the purpose of finding a northwest

passage. On the 26th of March, 1616, the Discovery, a craft of only 55 tons burden, commanded by Robert Bylot, with William Baffin as pilot, left Gravesend, with orders to follow the west coast of Greenland to the 80th parallel, and then to run southwest to the 60th parallel, in order to make the "Land of Yedzo."

On the 14th of May the vessel found itself in Davis Strait, latitude 75° 20′ N., and a week later it anchored in a bay on the "London Coast." On the 30th, Hope Sanderson was reached, the farthest point attained by Davis in 1587. Here extensive fields of ice were encountered, but they were successfully traversed in two days. A strong head wind compelled the navigators to anchor within a cluster of islands, to which they gave the name of Women Islands, from the fact that the Eskimo women showed more courage than the men, who, at sight of the strangers, decamped hastily. Keeping the coast of Greenland to the right, the navigators took a northerly course, but were soon stopped by ice, and were obliged to anchor in latitude 73° 45′ N., in a sound which they called Horn Sound, on account of the large number of narwhal tusks they obtained from the natives.

Sighting open water, the northerly course was resumed on the 18th of June. Baffin was delighted to find himself in an open sea, and believed that he had discovered the much-coveted passage. On the following day, in latitude 76° 35′ N., a high cape came in sight, which received the name of Cape Dudley Digges, and twelve leagues farther to the north a large sound was named Wolstenholme Sound, in honor of one of the patrons of the enterprise. In latitude 77° 30′ N., on July 4th, they ran into a strait which was named Whale Sound, on account of the many whales that were seen. Stormy weather compelled the navigators to anchor in a small bay, which they left before the following day, when they passed Hakluyt Island and discovered another sound, extending beyond the 78th parallel, where Baffin was greatly astonished to find a westerly variation of the compass amounting to not less than 56 degrees. This channel was named Sir Thomas Smith's Sound, and the islands in its meridian the Carey Islands.

As the compact nature of the ice-fields checked all farther progress towards the north, the explorers followed a southwest course, favored by a strong breeze. The fog, which had shut out everything from view for several days, disappeared on the 10th of July, when they found themselves close to the coast in Sir Alderman Jones Sound. An attempt to land proved impracticable on account of stormy weather; they therefore proceeded to the southward. Their hopes of finding the longed-for passage diminished from day to day; so

they decided to bear up for home, and reached England on the 30th of August.

Never before had fortune favored a navigator as it had the daring commander of the Discovery, who, on the memorable fourth day of July, attained the highest latitude west of Greenland, a latitude not again reached during the two following centuries. Unfortunately, the memory of this marine exploit was stained by the partiality of John Barrow, the English geographer, who credited only those discoveries that were made by officers of the Royal Navy. But even if the manuscript reports of Baffin had not been preserved in the British Museum, the reputation of Baffin and Bylot as naval heroes would still have been established by a subsequent English expedition, and the calumnies brought to light, as we shall see hereafter.

The wars which, at the beginning of the present century, preoccupied the European nations, had barely ceased when Arctic exploration was resumed. The English whalers visiting the Arctic seas having for three successive years reported on the favorable condition of the ice and the comparatively easy navigation of those seas, the English government resolved to send out two independent expeditions in search of the Northwest Passage; one, to push through Davis Strait; the other, through the sea east of Greenland. It suffices for our purpose to consider only the expedition which, commanded by John Ross, left England on the 25th of April, 1818, and followed in the wake of the Discovery. This expedition consisted of two well-equipped vessels, the Isabella and the Alexander; the former was commanded by Ross himself; the latter, by Lieutenant Parry. On the 1st of June they both entered Davis Strait and shaped their course along the coast of West Greenland. On the 22d they crossed the 70th parallel, after having been beset by ice the day before, and advanced slowly northward, making a hurried survey of the coast, which in several places they found to have been laid down almost ten degrees too far to the east.

Gradually they approached the scenes of Baffin's and Bylot's discoveries.* On the evening of the 17th August they sighted the

* Strange to say, this verification of the coast-line has never been mentioned by the writers of Arctic history, although Ross gives a very instructive and graphic representation of his surveys and of those of his predecessors. Compare Ross, Voyage of Discovery, frontispiece, where the coast of Greenland is represented in solid and dotted lines.

Cape Dudley Digges of the Discovery, and on the following afternoon, in Wostenholme Sound, Ross attempted to land, but was prevented by a dense fog. However, towards 9 o'clock the Carey Islands came in sight, corresponding exactly with Baffin's description. The sea was comparatively free from ice, but the violence of the wind from the north prevented him from landing.

Cruising in the vicinity of the islands during the night, the vessels found themselves at 8 o'clock on the morning of the 19th opposite the western coast of the group; they then started on a northeasterly course to examine more closely Wolstenholme Sound. Satisfied that farther progress in this direction was impossible, Ross returned to the Carey Islands to take on board the officers whom he had left on an ice-field to make astronomical observations.

At midnight of the 19th the expedition reached its highest point, which Ross gave as in 76° 51′ N. latitude, 74° 20′ W. longitude; but the absence of reliable astronomical observations may possibly have caused some inaccuracy. The 77th parallel, however, which had been bravely crossed by Bylot and Baffin, was hardly reached by Ross, although his ships were strong men-of-war; and no new laurels were won by the commanders until the following year, when Parry performed a daring exploit. Smith Sound was sighted by Ross, who designated it a *cul de sac*, and on his charts conjured up imaginary mountain ranges barring a northerly exit. In the same manner he treated the sounds bearing the names of Jones and Lancaster.

Although considered a failure, this expedition, returning to England on the 30th October, was not without some good results. Evidently its greatest success lay in the fact that it induced England to engage in new enterprises which became of vast importance to the geography of the Arctic region, and tended to increase our knowledge of the north coast of America and its islands. The more special results were: the discovery of the red snow which gave name to the Crimson Cliffs; a greater knowledge of those Eskimos who extend their wanderings into Smith Sound; some soundings, and the mapping of some portions of the coast.

Unfortunately, Baffin's original chart has been lost, but Petermann very ably drew an outline of the cruise from the descriptions found in the old manuscripts. A comparison of this chart with the representation of Ross's survey north of the 75th parallel must elicit our admiration for the work of the old navigators. And we ought to excuse any uncertainty of the geographical positions, for it must be remem-

bered that in those times, only the infrequent eclipses of the sun or of the moon could be used for accurate determinations of longitude; and, in consequence of the imperfection of the nautical instruments of those times, it was not until sixty years later that the occultations of the satellites of Jupiter could be utilized; even the dimension of a degree of longitude at the equator had not then been exactly determined.*

The Bylot-Baffin survey, considered in its entirety, gives by far a more correct representation of the northern outlets of Baffin's Strait than the chart of Ross, which was magnificently engraved on copper in artistic style, but which owes many of its interesting details to mere imagination, which created mountains in places that Ross intentionally or unintentionally did not reach. A critical comparison of his work with that of his successors will show that many of the localities named by him have no existence. If any one will take the trouble to compare the conflicting descriptions, he will be convinced that such is the case; for instance, Cape Isabella and Cape Alexander, flanking the entrance of Smith Sound, cannot possibly be the same capes as those to which Ross gave the same names. For more than two centuries they had been the northern Pillars of Hercules, and they were destined to hold this position for a quarter of a century more. In the meantime, steam power had taken its place in navigation.

* The accuracy of the geographical positions determined by Bylot and Baffin may be due to the circumstance that these navigators perhaps used an astrolabe instead of a cross-staff to measure solar altitudes. Inasmuch as their vessel was frequently surrounded by ice, there was nothing to interfere with the reliability of the former instrument. For the ice acts like a breakwater, entirely deadening the swell, and a good astrolabe, according to the statement of Tycho Brahe, read to one-sixth of a minute of arc. In the latitude where the navigators made their surveys, the meridian altitude of the sun did not exceed 45°. At that time the tables of refraction commonly in use were those published by Tycho, which were based on the erroneous supposition that altitudes higher than 45° were not influenced by refraction. Consequently, they avoided errors which, in some instances, especially in high latitudes, could easily amount to a minute of arc.

To demonstrate further the accuracy of the observations made by Bylot and Baffin, I will only state that astronomers like Regiomontanus and Peurbach made latitude observations which were 26′ (Venice) or even 27′ (Nuremberg) in error (see Alfontii Regis Castellae Tabulae, impr. Erhardus Ratdolt). Their instruments were certainly not less perfect than those of the English navigators; for, up to the time when Hadley invented the octant, the nautical instruments were very little different from those of the Arabs and the ancient Greeks.

Subsequently to the Ross expedition, the English government, still searching for the Northwest Passage, sent out in 1847 the expedition under Sir John Franklin. Alarmed by his long absence, Lady Franklin in 1852 sent to his rescue a small steamer, the Felix, under Commander Inglefield. The instructions of Inglefield were to take provisions to the English squadron in Barrow Strait, and then to search for the lost navigators in the northern extremity of Baffin's Bay. This vessel, with a crew of seventeen persons, including the commander, left the Thames on the 4th of July, 1852, the same date as that on which Bylot and Baffin reached their highest latitude. On the 20th of August it made Cape York. On the following day the explorers landed at the Eskimo settlement in the vicinity of the Petowak glacier, and, two days later, at North Star Bay, and, on the 25th, at Bardin Bay. Thence, penetrating through Smith Sound, they reached latitude 78° 28′ 21″ N. on the 27th of August. Inglefield had thus exceeded Bylot's and Baffin's latitude, and saw before him an apparently open sea; but, on account of stormy weather and the advanced season, as well as the insufficient preparations for wintering his small vessel, he was compelled to return.

The most northerly land that he sighted on the east coast of the sound was in about 79° 32′ N. latitude. He represented it as a projecting cape, and named it after Frederick VII. of Denmark. The most northerly point on the west side, in about the same latitude and in W. longitude 79°, was named Victoria Head; while a small island, situated about midway between these two positions, which, however, was never again seen, was named Louis Napoleon.

Considering that Inglefield spent scarcely fourteen days in that region, we are astonished at the large amount of valuable material which he and his scientific companion Sutherland collected. Geographical knowledge was enriched by the survey of about 180 miles of coast-line; terrestrial physics, by a valuable meteorological record and numerous hydrographic observations; and, lastly, natural history profited by their collections.

On the 1st of September the explorers proceeded to Jones Sound, running in a westerly direction; on the 2d they left for Lancaster Sound, and on the 10th of November the little steamer was once more anchored safely in Peterhead.

The first expedition that entered Smith Sound fully prepared to winter, sailed under the American flag, and attained a higher latitude than any of its predecessors. It was commanded by Elisha Kent Kane, an officer of great energy, whose health was so much impaired by this campaign that he died soon after his return.

The expenses of the first American Franklin Expedition were defrayed wholly by Henry Grinnell; those of the second were sustained by him in conjunction with Mr. George Peabody. The United States Navy, of which Kane was an officer, furnished ten men and a portion of the equipment. The Advance left New York, May 30, 1853; her crew consisted of eighteen men, including the commander. After touching at St. John's, Newfoundland, the explorers arrived at Fiskernaesset on the 1st of July and at Upernivik on the 17th. Here they obtained a supply of furs and dogs and secured the services of a Dane and an Eskimo. Ten days later, Wilcox Point was passed, and, soon after, the explorers entered Melville Bay. The ice along the shore was rotten and threatened to break up. Kane, therefore, in preference to the ordinary course along the edge of the ice, took the middle passage until stopped by heavy floes. He then coasted to Cape York, doubling it ten days later, and entered Smith Sound on the 7th of August. As far as the eye could see, there was open water to the northward, with a promising swell from the same direction. The wind was variable, blowing mostly fresh from the south and west.

Aside from the difficult task of towing the vessel through the heavy ice, the voyage had been favorable, and with new hopes the explorers sighted the open sea. Their joy, however, was of short duration; the wind veered and blew strong from the north; and, nearing Inglefield's Littleton Islands, the pack was observed a short distance ahead. On the largest of the islands Kane erected a cairn, within which he deposited information regarding the success of the expedition; and *cached* a boat with provisions on a peninsula, to provide for the contingency of the disabling of the vessel.

In order to proceed farther it was necessary to force a passage. The first attempt was made during the night of the 7th. The ice was very thick and apparently several years old; therefore but little progress was made. About forty miles north of the place where the depot had been established the vessel came to a stop. The ice closed around it, and it was saved from going ashore only by an eddy. The danger during the next three days was imminent, but on the 13th the Advance succeeded in escaping to the westward. But here, too, the

ice was unexpectedly heavy; the days grew shorter, and it was feared that winter would set in and leave them to the mercy of the drifting pack.

Amid these difficulties the Advance reached her most northerly position, 78° 43′ N. latitude, on the 29th of August. She was damaged to a considerable extent; the bulwarks were partly demolished, the bow and one of the boats were stove, and more than 600 fathoms of cable with one of the anchors had been lost. The crew worked with unremitting zeal until the 1st of September, but to no purpose. The brig was sheltered in a bay along the coast, and Kane, accompanied by some of his men, advanced northwardly by boat and sledge to reconnoitre the condition of the ice. From an elevation of 1100 feet he could overlook the sea to the 80th degree, and he found it frozen solid, with numerous icebergs.

Fully convinced that farther progress by vessel was out of the question, Kane returned to the brig, and found the shelter he was in sufficient for the time being; deciding therefore to establish his winter quarters at this point, he commenced preparations at once. Later on, he sent a sledge-party for the purpose of establishing a depot as far north as possible, to aid in the journeys contemplated for the next spring. Two shorter explorations were made; one into the interior of the country for the purpose of reconnoitering, and the other to a point, northerly, on the coast, to deposit a self-registering thermometer.

Kane named his winter-quarters Rensselaer Harbor, and here an observatory was erected, the position of which was determined as N. latitude 78° 37′ 04″, and W. longitude 70° 52′ 45″. Never before had an expedition supplied with proper instruments wintered in so high a latitude, and we may therefore justly consider the magnetic and meteorological observations made during Kane's stay in Rensselaer Harbor as important contributions to terrestrial physics, and the series of astronomical observations may be regarded as equally valuable.

The sun disappeared on the 10th of October and remained below the horizon for 120 days. The sanitary condition of the crew was excellent, but a great mortality prevailed among the dogs, of which fifty-seven died, the pack being reduced to a very small number. As the execution of Kane's plan of operations depended almost exclusively on these animals, it was a very fortunate circumstance that in April a band of Eskimos visited the harbor, from whom Kane obtained an additional number.

Low temperatures delayed the sending out of sledges until the second half of March. On the 19th a small party started to establish

a depot at a distance from the vessel of ten days' journey. In the meantime, preparations were pushed forward to get ready the principal exploring party, whose object was to search for traces of Franklin along the northern prolongation of the sound. Three of the men sent out returned quite unexpectedly in a deplorable condition on the 31st. Cold and hunger had almost deprived them of speech, and it was a long time before they were able to give an account of their companions. They had left them somewhere north of the brig, between the hummocks. Four of them were helpless, perhaps frozen, and a fifth, in tolerable condition, had remained behind to nurse them. When they started to obtain help a severe snowstorm had set in. That was all the exhausted men were able to tell, after risking their own lives to obtain help and assistance for their comrades. Without delay, Kane had a sledge equipped, and the man who had suffered least was enveloped in buffalo skins and tied to the sledge, to serve as a guide. Kane, with nine men pulling the sledge, started. The thermometer read 43 degrees below zero. It became, therefore, necessary to proceed with all possible speed to save the lives of the others. Unfortunately, Ohlsen, the man on the sledge, who had marched fifty successive hours without food, and who was now perfectly exhausted, commenced to show indications of delirium and could give no answer to questions put to him. The party proceeded at random after having been on the march eighteen hours. Kane ordered the men to disperse, leaving the sledge behind. The experienced eye of the Greenlander Hans discovered a trail, which he and Kane followed for a couple of hours, when they noticed a flagstaff, from which the Union flag and a little Masonic banner floated. Close by the tent, completely covered by drift snow, the men were found alive, but their hands and feet were frozen, so that they were unable to move. After resting a short time, the sufferers were sewn up in furs, packed on their sledges, and, by hurried marches, the party returned to the brig. The temperature fell to —48° ; the men had recourse to snow to quench their thirst. All were attacked by that irresistible sleepiness which intense cold generally produces, and it was only by the energetic exertions of the leader that they were saved from freezing. They returned to the harbor after an absence of eighty-four hours, during which they had had only four hours' rest. Two of the men died soon after the return, and most of them lost portions of their extremities by amputation. All suffered from brain affections, which resembled temporary insanity, and all were confined to their beds for a long time.

It was not until the end of April that the health of the crew permitted any travelling. After despatching a small number with provisions, Kane, accompanied by one man, started on the 27th in a dog-sledge on a journey northward. The ice was almost impassable and progress difficult. On the 29th he came to the sledge that had been sent forward with provisions, but the way grew worse. Scurvy appeared among the crew. One after another became incapacitated, and the expedition again failed. Kane himself was so weak that he had to be carried over the worst places, while on a level road he had to keep to his sledge. Returning to the brig on the 14th of May, he became unconscious.

Under these circumstances, however, he had no time to be sick; his active mind thought of new means to accomplish the object of the expedition. The ice to the north having proved impassable, he despatched, on the 20th of May, a sledge that was to cross Smith Sound south of the harbor, and to penetrate northward along the west coast. This expedition was entrusted to Dr. Hayes, accompanied by one seaman. Instead of following Kane's instructions, Hayes at once struck northward, and was so fortunate as to approach the coast on the 25th, in latitude 79° 24'. After having overcome the greatest obstacles, the travellers found themselves affected with snow-blindness; on the 26th, Hayes' companion became wholly blind; on the following day the dogs gave out, and finally the sledge broke. Undaunted, the discoverers continued their northward march; on the 27th, in W. longitude 69°, they reached their highest latitude, 79° 45'. After making a hurried survey of the coast, they returned, reaching the brig on the 1st of June, after an absence of twelve days.

This expedition gave a fair account of the coast line of Grinnell Land as far north as the 80th parallel; but the west coast of Greenland was still shrouded in mystery. Notwithstanding all the exertions, it had not been possible to reach the northern side of the great Humboldt Glacier, that immense wall of ice, which, commencing at Cape Agassiz, beyond the 79th degree, extends north as far as the eye can reach.

On the 4th of June, Morton was directed to solve this problem. After preparing his stock of provisions, he left the depot on McGary Island on the 18th, in a sledge, accompanied by the Greenlander Hans. The detachment that had accompanied him thus far returned to the brig, and the others started on their northward journey at half-past-twelve in the morning. Soon after setting out, they

found themselves in the labyrinth of icebergs which on a previous occasion had prevented the progress of one of Kane's expeditions. Frequently, in order to find an outlet from one of the "blind alleys" into which they had ventured, they found themselves compelled to turn back, after having accomplished a mile or more to the north; frequently they had to bridge over wide fissures in order to proceed. The difficulties increased, but they continued in their onward march. On the morning of the 20th they sighted land to the west, an indication of the narrowing of the sound. Thus far they had moved in the direction of the great Humboldt Glacier without seeing the opposite coast. An observation at noon of the 21st showed them that they had gone one mile beyond the 80th degree of latitude; both shores were visible; they had reached the northern side of the glacier, and in front of them steep rocks formed the continuation of the picturesque coast. There they deposited one-half of their supplies in a cave and continued on their course. Towards evening they saw open water at a distance, while flocks of eider-ducks, geese, and dovekies rose in the air, and from the cliffs the cries of the burgomaster and ivory gulls were heard. The ice became thinner and bent under the weight of the sledge; the terrified dogs refused to proceed, and it was only with great difficulty that the sledge could be saved from breaking through before they reached the firm ice. During the 22d, fifty miles were covered, and they succeeded in crossing the icy barrier that skirted the coast. On the opposite side, Grinnell Land appeared to extend northward in a straight, unbroken line. A severe storm prevented the continuance of the journey until the morning of the 23d; and then they had hardly proceeded six miles when the shore ice disappeared. Leaving the sledge, the travellers worked their way over floating pieces of ice, and after proceeding about four miles they sighted towards the north a projecting cape and an island. They then returned to the sledge.

On the morning of the 24th the attempt was renewed, but the difficulties proved greater than on the preceding day. The way grew worse, and finally the travellers were compelled to creep over the narrow shelves on small projections of the cliff. The belt of ice had wholly disappeared; only isolated pieces were floating on the dark waters, and were breaking up noisily as they crashed against the rocks at the feet of the travellers. From the north a swell was observed, indicating proximity of open water. They failed in their attempt to reach the cape, which they named Cape Constitution. Hans grew

tired and fell behind. Morton ascended a slope of about five hundred feet in the vicinity of another cape (Cape Independence), and saw before him an apparently open sea, and in the northwest the horizon covered with dark rain-clouds. Northward, disappearing in perspective, the coast of Grinnell Land could be traced, the most distant point of which (Cape Parry) he estimated to be in N. latitude 82° 30′.

After once more attempting to double the cape, the travellers returned to the sledge on the 25th. A meridian altitude of the sun on the next day determined the position of the camp at 80° 20′; but as Morton estimated his northward journey twenty miles farther, he had reached N. latitude 80° 40′.* In the vicinity of his camp he noticed a strong southerly current. A brisk northerly wind swept through the channel, but no ice was visible. At four o'clock in the afternoon of the 26th the travellers retraced their steps and returned to the vessel, reaching it on the 4th of July.

It is probable that subsequent exploration of the Smith Sound region would have resulted differently if Kane had been satisfied to publish the simple report of Morton, from which the above account has been taken. The same might be said if an excellent paper by Rink had received due weight (see Journal of the Royal Geographical Society, vol. XXVIII., on the discoveries of Dr. E. K. Kane, 1853–55, by Dr. H. Rink). Kane, with an adventurous turn of mind, which may be recognized on every page of his narrative, clothed the observations of Morton with adventitious colors, which has led uncritical minds to accept this account literally. It would be unjust in the extreme not to acknowledge his merit. But it certainly was not an important gain to geographical science to have him proclaim the existence of a polar sea, kept open by the warm waters of the Gulf stream.

* Kane placed Cape Constitution, which is scarcely five miles north of Cape Independence, in latitude 81° 22′ N., almost twenty-two miles farther north than he was justified. Morton, on his northern journey, took astronomical observations and kept an itinerary in which he noted the estimated distances travelled. Instead of using the former, Kane took the mean of the two, thereby giving rise to various errors; for, a person not very much experienced in Arctic travel will invariably overrate his distances.

Five years after Kane's narrative had been published, the Smithsonian Institution issued a volume containing the astronomical observations made during the expedition, whereby the original chart was greatly changed. (Compare Physical Observations in the Arctic Sea, by E. K. Kane, reduced and discussed by C. A. Schott, Washington, 1859–1860).

How far the final positions given therein are correct, we shall see hereafter.

Kane, in his official report to the Secretary of the Navy, gives the following summary of the geographical results hitherto obtained by his different sledge-expeditions:

"1. The survey and delineation of the north coast of Greenland to its termination by a great glacier.

"2. The survey of this glacial mass and its extension into the new land named Washington.

"3. The discovery of a large channel to the northwest, free from ice, and leading into an open and expanding sea, equally free. The whole embraces an iceless area of four thousand and two hundred miles.

"4. The discovery and delineation of a large tract of land forming the extension northward of the American continent.

"5. The completed survey of the American coast to the south and west as far as Cape Sabine, thus connecting our survey with the last determined position of Captain Inglefield, and completing the circuit of the straits and bay heretofore known at their southernmost opening as Smith Sound."

The discoveries of subsequent expeditions to Smith Sound will furnish us the means of testing the correctness of this statement.

With Morton's sledge-journey the geographical labors of the expedition may be considered as closed. Only a few unimportant discoveries were made after that, but we must record a chapter rich in disasters, sufferings, and daring deeds. The vessel was provisioned for only one year and a half; and yet at the expiration of a twelvemonth the brig was still fast in the ice. On the 12th of July, Kane, accompanied by a small but picked crew, started on a boat-journey to inform the commander of the English squadron of his condition. He counted on the presence of an English vessel in the vicinity of Beechy Island, near the entrance to Wellington Channel, a distance of more than four hundred miles. On the 6th of August he returned to the brig, but without having accomplished his object. The heavy pack south of Cape Parry had frustrated every effort. There was no prospect of freeing the vessel during the year 1854, and he at once commenced making preparations to winter a second time. This required more than ordinary courage and devotion; for, the provisions and fuel had almost been consumed and the resources of the country were extremely scant. Besides, the health of the party had sensibly declined; their physical energies were weakened. Only fifty gallons of seal oil had been saved from the summer's hunt; the dried fruits seemed to have

lost their efficacy, and the store of molasses was reduced to a minimum. A single apartment was bulkheaded off amidships as a dormitory and abiding-room for the entire crew ; and a covering of moss, gathered with great difficulty from the frozen cliffs near the harbor, enclosed it like a wall. A similar cover was placed on the deck. The explorers, as far as possible, adopted the habits of the natives; they dressed entirely in skins, and organized daily hunting-parties which were hardly ever successful. The nearest winter settlement of the Eskimos at that time was about seventy-five miles distant by dog-journey; but, nevertheless, the ice-bound crew of the Advance entered into regular communication with the good-natured natives, from whom they now and then obtained some bear-meat, seal, and walrus, which were eaten raw. A small party of the crew, who, towards the end of August, had made an attempt to reach one of the Danish settlements, returned to the vessel after more than three months of intense sufferings. The noble commander gave them a brotherly welcome and shared with them what remained of the stores, although at the time of their leaving the brig to seek more genial surroundings he had allotted to them already more than cold prudence would have dictated to a man less generous than Kane.

After the gradual return of daylight the commander finally determined to abandon his vessel. Scurvy, with varying phases, had prevailed among the heroic little band. For many days Kane and one of the officers had been the only persons able to carry on the daily work and to attend upon the sick. They were even deprived of the services of the surgeon, whose frost-bitten toes had to be amputated.

The organization for their escape was matured with the greatest care. Three boats—two of them whaleboats twenty-four feet long, and a light cedar dingy of thirteen feet—were supplied with runners, cut from the cross-beams of the vessel, and bolted, to prevent them from breaking. These runners were eighteen feet in length and shod with hoop-iron. No nails were used in their construction; they were lashed together, so as to form a pliable sledge, and upon it the boats were so cradled as to be removable at pleasure. Another sledge, with a team of dogs, was reserved for carrying the stores, and also for the transport of the sick, four of whom, on the 18th of April, were still unable to move. About thirty-five miles southward of the brig there was an old deserted Eskimo hut. This was fitted up to serve as an entredepôt of stores, and as a wayside shelter for those of the party who were already broken down or who might yield to the first

trials of the journey. The cooking utensils were very primitive. They were made of an old stove-pipe, and consisted of simple soup-boilers, enclosed in a cylinder to protect them from the wind. A metal trough filled with fat and provided with wicks of moss and cotton canvas formed the stove. The provisions, with the exception of tea and coffee and a few small stores for the sick, consisted exclusively of melted fat and powdered biscuits. They were packed in water-proof bags, adapted in shape to the sheer of the boats, and in no case rising above the thwarts.

The clothing was limited to a fixed allowance. Moccasins for the feet were made of woollen carpeting, and numerous changes of dry blanket-socks were kept for general use. For bedding, to the few buffalo robes left were added eider-down coverlets. Varied experience gained on former trips had taught the leader that, next to diet and periodical rest, good bedding and comfortable foot-gear were the most important things to be considered.

Kane himself transported the sick and the invalids, besides the reserve of provisions. The first load of stores was carried south in April, by the only dog-team at the disposal of the party ; and on the 15th of May the invalids were removed. By the middle of June all the disabled men and some twelve hundred pounds of stores had in this manner been transferred by a series of journeyings equal in the aggregate to a distance of eleven hundred miles. Two days later the sledge-boats left the vessel, dragged by the officers and men. The natural history collections were also carried as far as the sick station at Anoatok, but the weary travellers had to abandon them there for want of room. It was only with the utmost difficulty that they could carry the chronometers and such magnetic and meteorological instruments as might allow them to verify the observations made in winter-quarters and at different other stations. The more bulky apparatus, as well as the library, had to be left behind. Only the log of the vessel and the various documents of the expedition could be given a place in the boats. The distance made good during the first week was scarcely fifteen miles, and, although the rate of transportation was afterwards increased, it never exceeded three and a half miles a day over the ice, involving from twelve to fifteen miles of actual hard travel. To sustain the party, Kane found it necessary to return from time to time to the vessel, and to make dog-journeys to the southern settlements of the Eskimos. The last visit to the brig was on the 8th of June, for the purpose of procuring some pork to serve for fuel.

She was then in the same position as when abandoned on the 17th of May: "the same ice was around her still."

In the effort to liberate one of the sledges, which had broken through the decayed ice, Ohlsen, the carpenter of the party, received such serious internal injuries that he died on the 12th of June. He was buried on Littleton Island, opposite a cape now bearing his name.

Assisted by the friendly Eskimos, the party reached the margin of the floe six days later. During thirty-one days they had walked three hundred and sixteen miles, and had dragged their boats over eighty-one miles of rough, unbroken ice. The passage to Hakluyt Island was open, but as far as Cape York they met with nothing but solid pack, hanging around Murchison Sound and stretching to the westward. Passing over the solid land ice, they advanced only one hundred miles between the 20th of June and the 6th of July. On the 21st, Cape York was finally doubled, and, finding no natives, the explorers made immediate preparations to cross Melville Bay. Up to the 26th they followed the margin of the fast floe, resorting only twice to portage.

On the 6th of August, eighty-three days after they had left their desolate winter-quarters, they reached Upernivik, welcomed by the hospitable Danish officials, who provided for all their wants. They had already taken passage on board of the Danish trading-brig Marianne, to be landed at the Shetland Islands, when, touching at Disco, they were met by the vessels sent in search of them by the government. These, the United States barque Release and the steamer Arctic, commanded by Lieutenants Henry Hartstene and Charles C. Simmes, had penetrated as far north as 78° 32′ and had then fallen in with a band of Eskimos, who informed them that Dr. Kane, in company with his interpreter and seventeen others, had gone south in their boats. On the 11th of October, 1852, both vessels anchored at New York, restoring the explorers to home and friends.

The next expedition sent out to explore Smith Sound was likewise due to American enterprise. It was commanded by Dr. Isaac I. Hayes, who, as Kane's surgeon, had fully shared the fortunes of the Advance. After five years of incessant work in the attempt to arouse the interest of the public for the continuation of Arctic exploration, he finally succeeded, by the help of warm personal friends and scientific societies, in fitting out and provisioning the schooner United States, a craft of only 133 tons burden. With the intention of completing the

surveys so ably begun by Inglefield and Kane, he combined the purpose of attempting to reach the pole itself by way of Smith Sound, which he considered "one of the most promising gateways to the Open Polar Sea."

On the 6th of July, 1860, the vessel left Boston harbor with a complement of only fifteen persons, including the commander. Having crossed the Arctic circle on the 30th, they sighted the coast of Greenland on the following day in the latitude of Disco. Six days later they were at anchor at Pröven, a small Danish colony, where they expected to purchase the necessary dogs; but, being unable to do so, they pushed around to Upernivik, where they arrived on the 12th of August. Here the explorers buried the ship's carpenter, who had died of apoplexy during the previous night, and procured a number of strong dogs and six additional persons, half of whom were natives.

The colony was still in sight when the vessel encountered a line of icebergs of various shapes and dimensions. They seemed to be endless and numberless, and so close together that at a little distance they appeared to form a solid wall; but they were passed in safety. On the 21st a stop was made at Tassuissak, the northernmost settlement, inhabited by a few white men, and situated in latitude 73° 21′ N., longitude 56° 5′ 7″ W., and about one hundred and sixty miles north of Hammerfest, the *ultima thule* of civilization in the northern hemisphere. The commander intended to spend only a few hours at the place, but while the men were searching for sledge-dogs, a large quantity of ice closed the mouth of the harbor. Finally, on the evening of the next day the tide carried off the pack, and shortly afterwards the little schooner passed Cape Shackleton and the Horse's Head, and shaped her course for Melville Bay. By eight o'clock in the morning of the 23d of August, Wilcox Point was clearly in view, and the Devil's Thumb showed itself, partly hidden by floating clouds.

There was scarcely any ice in sight, except a few bergs with water-worn sides and rugged pinnacles. Melville Bay, apparently open, spread itself before the explorers. Up to that time a light wind had been blowing from the eastward, setting the pack toward the American side; a heavy swell was soon noticed, coming from the south and accompanied by a blinding snowstorm. The air was so thick that one could not see to a distance of ten yards, and it blew half a gale; still the schooner's head was pointed toward Cape York and the vessel went on her way under close-reefed sails. When it cleared again

the vessel lay becalmed not far from the centre of Melville Bay; the sea was dotted with icebergs, but there were no fields in sight. A quantity of the latter mixed with loose pack was met at noon of the 25th in latitude 75° 53′ N., but was successfully passed. Fifty-five hours after the explorers entered Melville Bay, they found themselves in the North water, standing close in under Cape York, with its snow-crowned highlands. A careful lookout was kept for natives. Passing along the coast within a rifle-shot's distance, the explorers soon noticed a group of human beings making signs to attract attention. A boat was lowered and a party landed to communicate with these Eskimos. Hans, whom Kane had taken on board his vessel in South Greenland, and who had deserted the brig to live with the wild Itah tribe, was among them. He instantly recognized Hayes and Sonntag, who had been the astronomer of Kane's expedition. Hans was accompanied by his young wife with a babe in her hood, and by several members of his family. He was anxious to leave his self-imposed banishment, and Hayes took him with his wife and child on board the schooner, which was reached early in the evening.

The wind having freshened, they set sail, and at eight o'clock were abreast of Booth Bay, the winter quarters of the small party who had left the Advance in 1854, and, led by Hayes, had made the fruitless attempt to reach one of the Danish settlements. Soon afterwards the sky became overcast, more heavy snow began to fall and the wind died away. Passing Whale Sound outside of Hakluyt Island, they sighted the entrance of Smith Sound on the morning of the 27th, and found a passage through the pack near the shore, off Cape Saumarez. Cape Alexander was reached without any difficulty, but not so the coast of Grinnell Land, towards which they now were standing. Large masses of ice were drifting down the sound before a northeasterly wind. Many of the floes were from two to ten feet above the water; the ice seemed to be interminable; not a single lead could be discovered in the direction of Cape Isabella.

Now, the northeast wind grew to a gale, and compelled the vessel to seek shelter near the shore. Not until three o'clock on the morning of the 30th did they come to anchor in a little cove near Sutherland Island. The stern of the vessel was swung round and moored to a rock, but the hawser parted, under the influence of a violent squall, and the schooner was lying to her bower and kedge with thirty fathoms of chain. After the gale had abated, the sea, from an elevation of 1200 feet, appeared to be free from ice along the shore as far

as Littleton Island, from which the pack stretched out over the North Water as far as the eye could reach. There also seemed to be open water about Cape Isabella, while beyond the cape the ice was solid.

The night of the 31st closed upon a day of disaster. The schooner was dragging her anchors; while the bower was saved, the kedge caught a rock. In a critical moment the hawser parted and the schooner was driven upon some bergs grounded astern. The stern boat was crushed, the bulwarks over the starboard-quarter were stove in, and, the schooner's head swinging round, the jibboom was carried away. The bowsprit and foretopmast were both sprung. But the vessel at last escaped, and under bare poles scudded before the wind. Shortly afterwards, when the pack and a vast number of icebergs came in sight, the explorers made sail; but the mainsail was blown away as soon as it had been set. They had before been blown out of the sound, and now this happened again. In the attempt at wearing the schooner, to avoid an iceberg, the fore-gaff broke, and, unable to carry anything but a close-reefed staysail, they found shelter near Cape Alexander.

Undaunted by these failures, Hayes, during the next two days, repaired damages, and again pushed northward. The southern margin of the pack had remained unchanged, but there was some open water between Cape Hatherton and Littleton Island. There the vessel entered the ice. After proceeding ten miles in a northwesterly direction, the channels closed up under the combined influence of a south wind and strong southerly current. The vessel fought nobly against the floes, which were pouring down the sound, but with little success, although all possible sail was crowded on. Owing to the accident to the topmast she could not carry any topsail, and therefore would work only slowly in stays. The danger of being nipped was great. In wearing round without having sufficient room, her starboard bow almost struck an ice-field a mile in width. Escape was impossible; so the helm was put up that she might take the shock squarely on the fore-foot, and when the collision took place the bows were deprived of their strong iron sheathing, and the cut-water flew in splinters. Clear of the floe, the schooner came again to the wind, and, through a narrow lead, emerged into one of the broader spaces of open water. Hayes was bound to get a clutch on Cape Hatherton as long as the vessel would float; but fate was against him. The ice closed in with the land, and the explorers were fast losing ground, as

before. Ere an hour had elapsed the schooner was fairly beset. She had been worked into a triangular space, formed by the contact of three fields, which now closed upon her like a vice. The deck-timbers were bowed up, the seams of the deck-planks opened, and her sides threatened to give way. Finally the ice hummocked under her bilge on the port side and lifted her partly out of water. During eight anxious hours she was kept in this position; then the ice relaxed and she gradually sank back. An inspection showed that the rudder was split, two of its pintles were broken off, the stern-post was started, and fragments of the cut-water and keel were floating alongside. Besides, the hold was rapidly filling with water.

The pumps having been manned, she was headed for Hartstene Bay, where she anchored. After it had been found that her damages were not so serious as had at first been supposed, and after the most necessary repairs had been made, she was again taken to sea. But owing to her crippled condition she had to be handled gently. Further progress north was now impossible. Hayes, therefore, on the 6th of September, turned back to Hartstene Bay and anchored in a small, well-protected harbor, which he named Port Foulke. For the position of the observatory subsequently erected he gives lat. 78° 17′ 39″ N., long. 73° 00′ W.*

If daring and enterprise alone could crown Arctic expeditions with success, Hayes would certainly have won imperishable laurels. But fortune refused to smile upon the harassed explorers, and notwithstanding all their earnest efforts they did not succeed in reaching a higher latitude than Inglefield had reached eight years before. When the temperature fell 10° below zero the crippled little schooner was fairly imbedded in her icy cradle. Meanwhile the cargo had been landed and taken to a small storehouse, built of erratic boulders found along the terraced beach, and roofed with sails. The hold of the

* Latitude 78° 18′ 30″ will be found to be more correct. In order to obtain the chronometric difference between Polaris House and Port Foulke, Mr. R. W. Bryan, Astronomer of the U. S. North Polar Expedition, was sent to the latter place on May 23d, 1873, to take some observations on the spot where Hayes' observatory had stood. As it was supposed that the latitude determined by Hayes was correct, it was not deemed necessary to redetermine the same. There is, however, a set of 15 double altitudes of the sun measured under very favorable conditions, about 2½ hours from the meridian, from which the latitude here given has been deduced. The observations were taken with a Gambey sextant, reading to 10″.

vessel was converted into quarters for the crew, and by the first of October it was ready for use. Mr. Sonntag, the astronomer of the expedition and second in command, with the help of his assistant, set up the different instruments, which now were in fair working order. Where Kane's half-starved hunters had in vain searched for game, Hayes found it in great abundance, the sportsmen hardly ever returning empty-handed. In the course of October they shot not less than seventy-four reindeer, twenty-one foxes, twelve hares, one seal, besides some thirty geese and other aquatic birds. They commenced the winter with a most encouraging prospect for an abundant commissariat, and everything looked bright and happy.

But soon all these fair prospects were changed, and various new mortifications and disasters awaited the explorers. Before midwinter had set in, most of the dogs had succumbed to the epidemic disease common amongst Eskimo dogs, and whose origin and nature are yet but little known. This malady broke out very suddenly. Up to the first of December the animals had been in perfect health; and, as they had been fed on an abundant allowance of fresh meat, Hayes was confident that he could carry them through to the spring. His fears, however, were for a time somewhat excited by the information received from Hans that the Eskimos of Whale Sound and vicinity, with whom he had been living, had sustained heavy losses by the death of a great number of their animals, and the description that he gave of this distemper corresponded with that observed in Southern Greenland. But as November passed and no symptoms of the malady had been noticed, he was hopeful that the dogs, upon which a great deal of the success of the expedition depended, would escape the visitation. The damage that Dr. Kane had suffered by the loss of his teams was still fresh in Hayes' recollection, but in this instance the cause of death seemed apparent. Kane had fed his teams almost wholly upon salt meats, which, giving scurvy to the men, could hardly be expected to act otherwise than injuriously on the animals, which had been used to a diet of fresh seal meat. During the first two weeks of December alone, Hayes lost eighteen dogs, which left him with only twelve; and these, one week later, were reduced to nine, and it seemed likely that the remainder of the pack would also die. Sonntag, therefore, volunteered to open communication with the Eskimos of Whale Sound, which had to be done at the earliest date. So he left on the 21st of December, accompanied by Hans, who drove his team.

A full month elapsed, and several days of the January moonlight, but still the travellers had not returned. The little band on board the schooner had grave cause to be alarmed. Sonntag and his companion must either have met with an accident or they must have been detained among the Eskimos in some unaccountable manner. Hayes, therefore, began to devise means for ascertaining what had become of them. After having sent out different parties to look for tracks in the snow near Cape Alexander, he concluded to search in person. A sledge to be drawn by men was ready and laden as early as the 27th of January, but a gale prevented the voyagers from leaving before the 29th. When about to start, two Eskimos were reported alongside the vessel, and the interpreter of the expedition interrogated them at once. What he had learned was only too plainly told by his face; the terrible truth could not be concealed—Sonntag was dead.

Two days later Hans returned to the schooner; some of his dogs had died and he had been travelling by slow and easy stages. From him the commander obtained a full account of the painful event. According to this statement, the travellers, after having rested at Sorfalik, set out for Northumberland Island, and when they had proceeded about five miles, Sonntag, becoming chilled, left the sledge and ran ahead of the dogs to warm himself. Hans, who halted for a few minutes to disentangle the lines, fell some distance behind, and, while hurrying on to catch up, suddenly noticed Sonntag breaking through the young ice. He hastened to his rescue and helped him out of the water; then he turned back to the snow-hut they had built at their resting-place at Sorfalik. As there was a light wind blowing, Sonntag did not stop to change his wet garments, but ran beside the sledge and thus guarded against danger. But after a while he rode, and when they reached Sorfalik, Hans found his companion stiff and unable to speak. Taking him to the snow-hut, he removed his frozen clothing, placed him in a sleeping-bag, and gave him some brandy. He then closed the doorway of the hut, and lighted the alcohol lamp to prepare some coffee and to warm the room as thoroughly as possible. But his efforts were to no purpose. The second day after reaching the hut, Sonntag died without having uttered a single word.

While the purely geographical results of the expedition had been seriously affected by the ill-favor of the elements, the progress of the scientific labors became greatly impeded by the death of Sonntag, who, as mathematician and astronomer, justified the highest expectations. Fortunately, he had measured a base-line in the vicinity of

the harbor, and had also commenced a trigonometric survey before the long night had set in; he had made a series of valuable pendulum experiments, and had mounted the instruments for the magnetic observations. But, although the work, once commenced, could be continued by Hayes and some of his companions, the results ceased to be of the same high order, for want of the directing spirit.

The sun, which had disappeared behind the hills of the harbor on the 15th of October, remained below the horizon for 130 days; but the winter passed without any grave consequences to the health of the crew. Hayes had obtained a number of strong dogs from the Eskimos, and preparations were being made for a start northward. On the 16th of March he left the harbor with two sledges to examine the condition of the ice, in order to ascertain whether it would finally be better to adhere to the Greenland coast, or to strike directly across the sound and follow the coast of Grinnell Land. To reach Rensselaer Harbor seven full days were required. The cold was so intense that on one occasion the temperature fell to minus 68½ degrees, while the minimum temperature at Port Foulke during the absence of the travellers had been only 27 degrees below zero.

The condition of the ice was very different from what it was in 1853–54. Then the coast-ice was smooth and the range of hummocks only commenced from ten to twenty miles from the shore. Now there was no such smooth track. Evidently the winter had set in while the ice was crowding upon the land; and the pressure seemed to have been tremendous. Numberless hummocks were piled upon old floes; the whole sea was one confused jumble of ice with peaks, spurs, and ridges separated by deep valleys; travelling was laborious in the extreme. Even in Rensselaer Harbor the party found a wilderness of hummocks at places where the ice had been perfectly smooth during the two years of Kane's sojourn.

Despite all difficulties, the journey was continued till Humboldt Glacier came in sight; but the ice grew worse and worse. From the top of a high berg, Hayes had a good view of Cape Agassiz, from which the trend of the great glacier appeared to be more to the eastward than it appears on Kane's chart. At the same times Hayes recognized the necessity of finding a more practicable route along the opposite coast, and, little pleased with his prospects, he returned to his winter-quarters.

The main expedition north had to be delayed on account of low temperatures. After having established a depot of provisions and

baggage at Cairn Point, the explorers left Port Foulke on the evening of the 3d of April. The party, thirteen in number, consisting of every available officer and man, was provided with two sledges, drawn by eight and six dogs respectively. On an additional sledge, drawn by eight men, was mounted a twenty-foot metallic lifeboat, with which Hayes hoped to navigate the Polar Sea.

The men, who had set out on their journey in excellent spirits and full of hope to reach the North Pole, or at least a very high latitude, soon became discouraged by the rapidly-increasing difficulties and obstacles. After several attempts to transport the lifeboat across the sound, it had to be abandoned at Cairn Point on the 7th of April, and the explorers thenceforth depended entirely on their sledges. The character of the route was bad beyond description; ridges of ice, sometimes over a hundred feet high, barred the way and had to be scaled. Unable to find a passage, the explorers often had to resort to pickaxe and shovel to make a track, only to find out at last that they had entered a *cul-de-sac*, necessitating their turning back and seeking for new routes, which seldom proved better. It was more than discouraging, that often, after a hard day's work, they found themselves only a few hundred paces from their last night's camp. In twenty-five days they had barely reached the middle of the sound, and this slow progress was enough to discourage the strongest.

But Hayes was not to be discouraged. He found that, in order to progress, he would have to change his plan of operation. Since he broke camp at Cairn Point he had made, in a direct line from place to place, not over thirty miles, while the number of miles actually travelled, counting all the various twistings and turnings and goings and comings, could scarcely be less than five times that distance. So, in the course of the morning of the 28th of April, he sent the main party back to the schooner, and continued the journey with only three of his most energetic men. These were Jensen, the interpreter, shipped in Greenland, George T. Knorr, the commander's secretary, and John McDonald, a man before the mast. The baggage and stores had been placed on two dog-sledges.

The difficulties and obstacles increased to such an extent that it required fourteen days to travel a distance of only forty miles. Completely exhausted, the explorers reached the coast of Grinnell Land on the 11th of May, and pitched camp under the imposing cliffs of Cape Hawks. It had required thirty-one days to accomplish this distance, which, in a bee line, amounts to only eighty miles. They had been com-

pelled to divide their baggage, in order to carry it on their shoulders over the roughest parts of the route, and to travel several times over the same ground. But now all hardship was forgotten; here was the land, and better times were expected to come. Of the eight hundred pounds of dog food that Hayes had taken with him when he sent back his men, only three hundred pounds were now left, and this could not last more than twelve days. After a hasty meal, the explorers left Cape Hawks, and found the coast-ice, though not very smooth, much more favorable to their progress. Now and then their route led them between the steep cliffs and an ice-barrier of probably fifty feet in height along the ice-foot. Without any serious interruption the journey was continued until the 15th, when Jensen, who had injured one of his legs, became quite helpless. He had to be left behind, and McDonald remained to nurse him.

Accompanied by Knorr only, Hayes continued his march until the 19th, when, according to his statement, he reached latitude 81° 35′ N., longitude 70° 30′ W., where further progress was prevented by thin ice, partly in process of dissolution. An open channel of water extended before him from Lady Franklin Bay to the eastward, and, widening, seemed to join other channels, until it was lost in an open sea. From an elevation of about eight hundred feet above the sea level, the sea had the appearance of "*a mottled sheet of white and dark patches, these latter being either soft, decaying ice or places where the ice had wholly disappeared. These spots were heightened in intensity of shade and multiplied in size as they receded, until the belt of the water-sky blended them all together in one uniform color of dark blue. The old and solid floes (some a quarter of a mile, and others miles across), and the massive ridges and wastes of hummocked ice which lay piled between them and around their margins, were the only parts of the sea which retained the whiteness and solidity of winter.*" Standing against the dark sky of the north, a noble headland, Cape Union, appeared in dim outline. Hayes judged it to be in latitude 82° 30′ North. Nearer to the explorers, Cape Frederick VII. and, somewhat nearer still, Cape Eugenie were sighted and named. Except the coast on which the explorers stood there was no land visible.

How far these statements and observations are correct we shall learn from the surveys of subsequent expeditions.

Having built a cairn, in which they deposited a brief record of their journey to this, their northernmost point, Hayes and his companion

returned by hurried marches. They found the two men where they had left them on the ice, and, after having lost eight of their dogs, they reached Port Foulke on the 3d of June. Hayes had intended to proceed farther north with his vessel; but a careful inspection of the schooner showed that she would not be able to stand any rough encounters with the ice. He therefore concluded to bear up for the United States, in order to have his vessel repaired, and to return the following year, accompanied by a small steamer, in order to establish a colony at Port Foulke. The observatory, filled with clothing and provisions, was left standing at Port Foulke, and the metallic lifeboat was concealed on Littleton Island.

The schooner left her winter-quarters on the 14th of June, and made a short stop on the coast of Grinnell Land, at Gale Point, about ten miles south of Cape Isabella, to which Hayes proceeded in a whale-boat. The cape itself could not be doubled, but from its summit he noticed that the sound was still full of ice; to attempt anything further with the schooner, therefore, would have been utter folly.

Giving a summary of his experience and the advantages gained for the future, he makes the following statement:

"1. I have brought my party through without sickness, and have thus shown that the Arctic winter of itself breeds neither scurvy nor discontent.

"2. I have shown that men may subsist themselves in Smith Sound independent of support from home.

"3. That a self-sustaining colony may be established at Port Foulke, and be made the basis of an extended exploration.

"4. That the exploration of this entire region is practicable from Port Foulke, having from that starting-point pushed my discoveries much beyond those of my predecessors, without any second party in the field to co-operate with me, and under the most adverse circumstances.

"5. That, with a reasonable degree of certainty, it is shown that, with a strong vessel, Smith Sound may be navigated, and the open sea beyond it.

"6. I have shown that the open sea exists."

His heart swelled by sanguine hopes, Hayes finally left Smith Sound, and after a short stop at Upernivik and Disco, he cast anchor in Boston harbor, on the 23d of October, 1862, after an absence of fifteen months and thirteen days. Unfortunately, his plans were never to be carried out by him in person. The Civil War in which his

country had meanwhile been involved put an untimely end to his explorations. He himself entered the army as surgeon, and the vessel that had so nobly fought against the Arctic ice he offered to the government as a gunboat.

Reviewing the results of the five different expeditions hitherto considered, we can divide the history of the discovery of Smith Sound and its northern extension into three well-defined periods. First, the period comprising the discoveries of Bylot and Baffin; second, the period comprising the discoveries of Inglefield; third, the period represented by the surveys of Kane. These were hardly carried any further by his successor than the discoveries of Bylot and Baffin had been extended by Ross two hundred years after the little Discovery had sighted the mouth of Smith Sound.

From the beginning of the seventeenth century to the return of the expedition under Hayes, adventurers and naval officers, philanthropists and men of science, had more or less faithfully devoted their lives and energies to increase our knowledge of that portion of the Arctic regions.

Fully ten years elapsed before the colors of the United States floated once more from the masts of a discovery-vessel in the Arctic regions. Meanwhile, Charles Francis Hall, born in the State of New Hampshire in 1821, had spent over seven years of his life in searching for the survivors of the Franklin expedition. He was a warm-hearted man, of large muscular frame, and of unbounded enthusiasm in the cause of Arctic exploration. His long sojourn among the Eskimos, following their own mode of life, had fitted him in every respect to withstand the rigors of the Arctic climate, even under the most unfavorable circumstances. Early in March of 1870, one of his friends from Ohio introduced a joint resolution in the House of Representatives to authorize the President of the United States to fit out an expedition towards the North Pole, and to place Hall in command of it. Thirteen days later, on the 25th of the same month, the unanimous consent of the Senate to submit a similar resolution was obtained. This resolution was referred to the Committee on Foreign Affairs, after having been read twice. Finally, on the 11th of June, the bill passed both houses, amended in such a manner that $50,000, instead of double that amount, was appropriated, and it was provided that the vessel should be furnished by the government, and that it should be commanded by any person fitted to lead an

Arctic expedition.* On July 12th, the act was approved by the President.

The Secretary of the Navy subsequently selected the United States steamer Periwinkle, a tug-boat of only 387 tons burden, which was rebuilt at the Washington Navy Yard. Having been newly timbered and her depth increased, her tonnage, when launched on the 25th of April, was about 400 tons. Her name was changed to Polaris. Commanded by Hall, she left New York on the 29th of June, 1871, with a complement of 23 officers and men. Besides the crew, we shall have to mention the Eskimo family, consisting of Joe, Hannah, and child—Hall's former travelling companions. Subsequently two additional officers joined the vessel at Disco, in Greenland, and at Upernivik the Eskimo Hans, with his wife and three children, was taken on board, thus increasing the number of souls to thirty-three.

The Polaris was provisioned and equipped for two and a half years. Her main object was to reach the North Pole, as may be inferred from the following passage, quoted from the instructions, signed by the Secretary of the Navy:

"Having been provisioned and equipped for two and a-half years, you will pursue your explorations for that period; but should the object of the expedition require it, you will continue your explorations for such a further length of time as your supplies may be safely extended. Should, however, the main object of the expedition, viz., attaining the position of the North Pole, be accomplished at an earlier period, you will return to the United States with all convenient dispatch." †

After having left New York, the Polaris touched at New London, where she remained until July 3. Making sail at daybreak, she left that harbor, and, after having passed Rave Rock at 5h. 20m., shaped her course for Newfoundland, reaching St. John's harbor near noon July 11, and remaining there till the 19th. The first port made in Greenland was Fiskernaesset, in latitude 63° 5′ N., longitude 55° 32.5′ W., where the vessel dropped anchor on the afternoon of July 27, and where she remained till daybreak of July 29. Coasting along the steep cliffs, Holsteinburg, in latitude 66° 57′ N., longitude 53°53.7′ W., was reached on July 31, at ten o'clock in the morning. Thence the

* The Statutes at Large and Proclamations of the United States of America, from December, 1869, to March, 1871. Boston, 1871, Vol. XVI., chap. 251, sec. 9, p. 251.

† Narrative, pp. 31, 32.

expedition started again at two o'clock in the afternoon of the 3d of August, arriving twenty hours later at Goodhaven, on the Island of Disco, in latitude 69° 14.7′ N., longitude 53° 34′ W. Here they had to await the arrival of the United States steamer Congress, a supply-vessel dispatched from New York. Having coaled and taken the stores and some sledge-dogs on board, the Polaris left Goodhaven at two o'clock in the afternoon of the 12th, and dropped anchor at Upernivik, in latitude 72° 46′ N., longitude 56° 2′ W., at half-past eleven the following day. She put to sea again at half-past eight in the evening of the 21st, and reached Kingigtok Island at eleven. Here she stopped for two hours to procure some additional dogs, and then made her way to Tassiussak, latitude 73° 21′ N., longitude 56° 5′ W., dropping anchor at half-past five in the morning.

Here Hall tried to secure the services of Mr. Jensen, the trader of the little post, who had accompanied Hayes on his expedition eleven years before. But Jensen could not be persuaded to join the Polaris, being unwilling to leave his family. Although it was perfectly clear and sunny in the harbor, a dense fog outside prevented the vessel from starting before the 24th of August. At fifteen minutes past two in the afternoon the Polaris weighed anchor and steamed out of the harbor, although the fog had not entirely dispersed. Piloted by Jensen, who was assisted by a son of the chief trader of Holsteinburg, she was successfully steered through the somewhat dangerous pass with its numerous islands and sunken rocks. When these gentlemen left, Hall sent his last dispatches. "The prospects of the expedition are fine; the weather clear and exceptionally warm; every preparation has been made to bid farewell to civilization for several years, if need be, to accomplish my purpose." Thus he wrote, full of hope and confidence.

Without having met more ice than an occasional floating berg or some solitary floes, the Polaris found herself in latitude 75° 56′ N., longitude 69° 26.5′ W., at noon the next day. In less than twenty-four hours Melville Bay had been crossed; what most of her predecessors had accomplished by more or less severe struggles, the Polaris achieved without the slightest effort.

At one o'clock in the afternoon Conical Rock was passed at a distance of eleven miles. It forms a steep islet of metamorphic rock, with almost perpendicular cliffs, bearing testimony to the former extent of the coast to the westward. An hour later Cape Dudley Digges was rounded, where, according to the instructions of the Navy Department, Hall was to erect a cairn and to deposit a record.

Ahead of us the sea was perfectly open, and, as even a short stoppage might have proved fatal to the further progress of the expedition, Hall concluded to pursue his course. Towards the north the Petowak Glacier now came in sight, a dazzling ice-stream, reaching the sea. It discharges numerous bergs, of which we counted about sixty in the vicinity of Conical Rock. Between the glacier and Cape Athol the land was almost free from snow.

About six and a half miles to the westward of this cape the cliffs of Wolstenholme Island rise boldly from the sea. If the cape is approached from the south, Saunders Island, situated a short distance to the northward, appears like an elongated high plateau, apparently connecting Wolstenholme Island with the mainland. This illusion, however, lasts only till Cape Athol bears about due east. Then the true character of the surroundings is at once revealed. The entrance to Wolstenholme Sound becomes visible, and on its northern shore we notice a conspicuous peak (Cape Abernethy?) of an altitude of probably 3000 feet, resembling the Matterhorn in Switzerland. Its top appears to be cut off in nearly a horizontal line, and it is surrounded by buttresses with perpendicular fronts, so that it seems as if a low cylinder was crowning the steep cone. Probably the latter is of volcanic origin, while the former seems to consist of metamorphic rock.

Passing between Wolstenholme and Saunders Islands, the entrance of Granville Bay, with the Three Sister Bees in front, was reached towards eight o'clock in the evening. The watch noticed a white streak ahead of the vessel, stretching in an easterly and westerly direction. When reached, it proved to be a seam of half-rotten ice, which could be passed without much difficulty. Through a veil of gray vapor, like dissolving views, the Carey Islands rose in the east, their outlines becoming more distinct, however, after Cape Wechmar was rounded. The distant land to the south had sunk below the horizon, Cape Athol appeared like an island behind Wolstenholme and Saunders Island, which we had passed a short time before.

Towards ten o'clock in the evening the vessel was abreast of Booth Sound, a deep bay with several ramifications; the scenery reminded me vividly of the picturesque shores of King's Bay in West Spitzbergen. The sound was still covered with smooth ice, evidently of one season's growth; the sombre peaks and dark hills bordering its shores were separated by rugged glaciers. The ice extended seaward to the precipitous flanks of Fitz-Clarence Rock, situated near the

middle of the entrance. A few flat "pancakes" drifted slowly in a northerly direction under the influence of the flood-tide. The surface of the sea was perfectly smooth. Only now and then a dovekey, a kittiwake, or a solitary male eider duck was observed. We tried in vain to find an explanation for the scantiness of the avi-fauna. The season was not sufficiently far advanced to cause the birds to leave that part of the Arctic regions, and we did not see any migrating birds, although the open water was very tempting to passing flocks.

At noon of the 27th the Polaris found herself in latitude 77° 51′ N., longitude 73° 44′ W. Up to this time the ice had in no instance interfered with her progress; she had approached the seventy-eighth parallel within a few miles. Towards the north the outlines of Cape Alexander became visible, while in the northwest Cape Isabella rose above the hazy sea, partly hidden by shifting fogs. Towards three o'clock in the afternoon the vessel entered Smith Sound. The look-out in the crow's nest having reported no ice visible, we steamed ahead, with mutual congratulations, at a speed of six or seven knots.

Since the early morning, Hans and his family had been on deck. We now approached the blessed shore where Mrs. Hans had first seen the light; where Augustine and young Tobias, some years before, had roosted in the hood of their mother's jacket, as little Susan was now doing; and where the whole family, with the exception of the broad-faced papa, had made their first acquaintance with soap and water, through the kind offices of Dr. Hayes. Mrs. Hans was greatly excited, but her husband's face had its usual wooden appearance. With the composure of a philosopher he scanned the shore with a spy-glass, looking for men, while little Tobias swallowed an immense chunk of raw beef, happy once more to behold his native land.

On we steamed, catching a glimpse of the head of Port Foulke, the winter-quarters of Hayes, and then passed Littleton Island, which we kept on our right. Near Cape Ohlsen, which rises behind this island, the general trend of the coast suddenly changes from northwest to northeast. As far as Cape Inglefield we steamed in the direction of the land, but now our course assumed a more northerly direction. From a distance we sighted Rensselaer Harbor, where Kane had spent two dreary winters, and shortly afterwards we passed without any difficulty the highest latitude to which his struggling vessel had penetrated eighteen years before. The more the shores of Greenland, veiled by a blue haze, dwindled in the distance, the more distinctly the features of Grinnell Land were revealed, with its grand alpine

scenery, and variously-shaped mountains and peaks, indicating a geological formation different from the metamorphic rocks of the opposite coast.

After having crossed the line of our maximum magnetic declination, which then was 109° W., we met the first real barrier of ice, which seemed to block the sound. This was towards midnight. It was, however, successfully passed, and the vessel reached the open water along the coast of Grinnell Land. At the same time a strong southerly current was noticed. Early in the morning of the 28th a boat landed in a small bight near Cape Frazer, to see whether it could be used as an anchorage in case the vessel should have to turn back. Hall did not consider the place suitable, and in less than a quarter of an hour the Polaris was again under way. Shortly afterwards a dense fog settled on the land, completely hiding the summits of the peaks. Towards ten o'clock it cleared, but only long enough to obtain a few altitudes of the sun. At noon the Polaris found herself in latitude 80° 3′ N., longitude 69° 28′ W.

The coast appeared quite different from the delineation given by Hayes, both with regard to topography and trend. This, in connection with the hazy atmosphere, and the comparatively great speed of the vessel, made it very difficult to identify the various points. In more than one instance we found it impossible to make the chart agree with the outline of the coast as it actually appeared. But under the existing conditions we could not even attempt to make a rough running survey. The main object of the expedition was to reach as high a latitude as possible, and we could not slacken our speed. So we contented ourselves with a panorama of the coast, drawn on a large scale, noting time and bearings, and the distances by two patent logs.

After crossing the seventy-ninth parallel, the Greenland coast could either be discerned only in dim outline, or else was entirely lost to our view. Towards two o'clock in the afternoon we again sighted the shore. The grayish-blue cliffs were partly hidden by opalescent, semi-transparent fog-banks, constantly changing their outlines and positions. The northerly breeze freshened, but the fog, instead of dispersing, only grew more and more dense. About three o'clock the velocity of the wind was 16 miles an hour. With the exception of a calm spell of short duration, on the day when we left Tassiussak, we had experienced only head-winds. A sailing vessel could scarcely have made any progress. Full of high expectations

we steered towards the open Polar Sea, which, according to Kane's statement, we expected to find north of Cape Constitution, and whose existence had been asserted by Hayes. Towards seven in the evening we sighted the cape, looming up through the fog, and in front of it, partially hidden by mists, we noticed Franklin and Crozier Islands, which served as landmarks. Without the islands we could scarcely have identified the place. Before the cape bore east we had already observed that the coast continued to trend in a northerly direction, but how far was impossible to tell on account of the increasing density of the fog. There could, however, be no doubt that we had not to deal with an extensive Polar basin, for we were steaming through a narrow channel, whose shores on both sides were distinctly visible. Cape Constitution had therefore ceased to be the North Cape of Greenland.

Early in the morning of the 29th, at half-past one, the Polaris passed between the coast of Grinnell Land and a small island, situated in latitude 80° 48′ N., which was subsequently named Hans Island. Even at that time it was not difficult to notice that the Greenland shore was still stretching to the north. Towards four o'clock the fog began to disperse, but shortly afterwards it grew so thick that we had to make fast to an ice-floe. About noon it cleared sufficiently to enable us to take a number of altitudes of the sun, which placed us in latitude 81° 21′ N., the approximate longitude being 64° 34′ W. Shortly afterwards we were under steam again, feeling our way through the misty atmosphere. About three o'clock in the afternoon we had the first glimpse of the distant land in the east, but for a short time only. In less than half an hour it was hidden again by dense fog. Towards four o'clock we passed through a narrow band of ice, consisting of fragments of moderate size and high hummocks. Since we had crossed the 80th parallel, only a few bergs had been noticed, but we had seen floes covered with coarse névé, projecting about three or four feet above the water. Now and then we saw the dim outline of the coast, but to get a clear idea of its character was still impossible.

During the night we were surrounded by fog, which gradually grew so dense that at nine o'clock on the morning of the 30th we were once more compelled to make fast to a floe. This floe appeared to be about two or three years old, had a rugged, uneven surface, and was about ten miles long. Some of the hummocks with which it was studded were from ten to twenty feet high, but its main surface was not over four feet above the water. Not a single bird was to be seen.

The only sign of organic life visible consisted in a few small ctenophores, swimming about in a lively manner among the floating masses of ice. The air was saturated with moisture, the rigging was covered with ice, and a dense layer of hoar-frost coated the bulwarks and the masts. During the afternoon it snowed for about three hours, but when it cleared at a quarter-past seven we noticed that the snowfall had not extended over a great area. The southern mountains and hills appeared dark and naked, while the land to the east and west was in its full winter attire. The vessel was unmoored and we steamed slowly ahead. To our right the lofty cliffs of the newly-discovered land came into view, and before us opened a wide bay, subsequently named Newman's Bay, the head of which could not be discerned from the crow's-nest. Never before had the keel of a vessel ploughed the sea which was now being traversed by the Polaris. Towards eight o'clock the ice increased in quantity, but as far as we could judge it consisted only of broken floes and hummocks; not a single berg was to be seen. Some of the fields were discolored by mud. The ice was setting south with increasing rapidity. At 8h. 56m. Hall attempted to land in a small bay. He used one of the whale-boats, but owing to the swiftness of the current he found it impossible to make the shore. Afterwards he tried it again, but with the same result. He therefore named the bight Repulse Harbor.

Following the open leads in various directions, we steamed ahead till half-past eleven, when we were again overtaken by a dense fog, which forced us to make fast to an ice-field. Toward midnight the current reached its maximum velocity of about four knots. The moon was almost full (29d. 18h. 20.8m.); it was probably the time of spring tide, and the velocity of the constant current was evidently increased by the influence of the tidal current. The set was towards the south, but it was impossible then to decide whether the acceleration was due to the flood or to the ebb. As we did not have any fixed point to which to refer the water-level, we attempted in vain to find out whether the tide was rising or falling; moreover, the sounding-gear, stowed in the hold, was not accessible.

At half-past six in the morning of the 31st of August we made a new start, but owing to dense fog the vessel had to be moored again to an ice-field at 7h. 50m. When it cleared, at ten minutes past nine, we continued our northerly course. We noticed more old floes than before; the hummocks increased in number and the open lanes grew narrower.

Budington, the sailing and ice master, whose courage and enthusiasm were not in proportion to his thirty years' experience, declared it impossible to penetrate any farther. He had sung the same song when we first met the ice in Smith Sound, but now he harped somewhat louder and in a higher key, and wished to turn back in search of a harbor. Hall, whose whole ambition was to attain the highest possible latitude, opposed Budington's views, as did every member of the expedition who took an interest in the enterprise.

It is always a disagreeable and thankless task to be compelled to discuss the qualities of a shipmate, and to criticize his actions, but at the same time it is the foremost duty of the historian to be accurate and impartial, even at the risk of touching an exposed nerve. In order to secure the highest degree of impartiality I shall now refer to the published testimony, as given before the Polaris Board, and, furthermore, I shall quote my own opinion expressed at the time, during a consultation held on the bridge of the Polaris, as repeated by Budington himself before the said Board. Budington's statement is as follows:

"Hall held a council with the officers, Dr. Bessels and myself, and the others,—which I have here, that was written down as it occurred, I believe, word for word. It reads as follows: 'Consultation held on board the Polaris in regard to getting further north with the vessel, the vessel being on the east side, looking for a harbor. Dr. Bessels, Mr. Meyers, Captain Tyson, Captain Budington, Mr. Morton, and Mr. Chester. Doctor wanted to cross the straits to look for a harbor, as being better for sledge journeys, while the east side was better for navigation, if we could not get further north. Mr. Morton coincided with Dr. Bessels. Mr. Meyer had the same opinion. Mr. Chester to get as far north as possible. Captain Tyson to get into harbor as soon as possible. Captain Budington to keep on east side as being better for navigation, and certainly better for sledge journeys. It was impossible to get further north on account of the pack. Go along the coast on the east side of the straits northward until a harbor is reached, which could be done in a short time. There had been seen one a few miles south of the present position of the vessel. It was decided by the commander to cross the straits. In doing so we got beset by the pack and drifted back about fifty miles.'"

Budington continues: "That paper was written down at the time, and it was the same in Captain Hall's journal, which unfortunately has been lost. It was left on the ice." When asked by the Secretary of the Navy whether the paper was in his own handwriting,

Budington answered: "No, sir; it was written by my instructions. It is a record of the consultation and opinions given at the time, written down by my instructions by Captain Hall's clerk, perhaps a week after it occurred. The same thing was written down by Mr. Meyers in Captain Hall's journal. Captain Hall once read it to me from his journal and I got the clerk to write down a copy of it, which is this copy."*

Mr. Budington was not an expert in the art of writing; so he had the "copy written down" by Hall's clerk about a week after the consultation had taken place. Why he had our respective statements committed to paper I will leave an open question. The solution of the problem, however, is by no means a difficult one.

It would be an injustice on my part to doubt the correctness of the "copy" unless sustained by the facts; but I feel compelled to state that we did not hug "*the east side, looking for a harbor*," but that it was the intention of the commander, and in accordance with his instructions, and his peremptory duty, to attempt reaching as high a latitude as possible.

As a matter of justice to myself I will also quote a paragraph from the official narrative, published by Rear-Admiral C. H. Davis, U. S. N., which reads as follows: "Dr. Bessels was of the opinion that it would be much better to reach the western coast, where a passage might be found to the north along the land, and where sledge-travelling in the spring would be more practicable."† That I was not very much mistaken in this opinion may be seen by consulting the results of a passage made by a subsequent expedition, which we shall presently have to consider; and that my statement could not have been influenced by any one on board can easily be inferred from the fact that I was the first person asked by the commander to express an opinion.‡

Mr. H. C. Chester was the first mate on board the Polaris. Let us now turn to those passages of his testimony relative to the movements of the vessel and the condition of the ice. He says: "On the thirty-first day of August, 1871, we got to the highest point we made. The steamer was stopped. We could see through the channel, and there was a water-cloud—a dense water-cloud—to the north. I mean a cloud that denotes open water. I think that we could have gone farther north from that point. It has always been my impression that we might have gone on. It was my watch below at the time. I heard

*Annual Report of the Secretary of the Navy for the year 1873, p. 447.

†Narrative, p. 92. ‡*Loc. cit.*, p. 92.

them sing out to the man at the mast-head, and heard the man at the mast-head sing out there was a lead close to the land on the east shore, and some one called me. I do not recollect who it was,* but some one called me and said that Captain Hall wanted to see me in the house. I went up, and when I got there the officers were all there and the scientific corps."†

The man at the mast-head, at the time mentioned by Mr. Chester, was Henry Hobby, from whose testimony I shall quote the following passages: "I was on the lookout at that time in the crow's-nest. From what I heard, all the officers wanted to go north. Captain Budington and Captain Tyson said it was necessary to make winter quarters as fast as possible. I could hear every word that was uttered. Captain Budington wanted to go into Newman's Bay; Captain Hall and all the rest wanted to go north, with the exception of Captain Tyson. . . . When I was up there in the crow's-nest, and they were talking about it, I could see a way for going north on the eastern shore, from north to about northeast.‡ So far as I could observe there was open water. . . . There was no ice between us and the open water that I saw. I sung out from the crow's-nest, inquiring where they wanted to go. I told them there was plenty of open water to the northeast. . . . Captain Budington said that we must make winter-quarters. These were just the very words he said. I asked him where he wanted me to go, and he said: 'Right over there, to Newman's Bay.' The ship was lying still at the time, under steam, and not fast; she was just lying there. There was no ice to stop us from going north, as far as I could see. We steamed across towards the west side."§

* It was William Nindemann, subsequently a member of the Jeannette Expedition.

† Report, pp. 480, 481.

‡ If the editor of the "Narrative" had studied the various documents of the expedition he would probably not have published the following sentence: "*The belief appears to have been unanimous that it was impossible to advance to the north along the eastern side.*" (Narrative, p. 93.)

When I proposed to the Commander to cross the strait and to follow the west coast, I did so because I considered it then, as I do now, a lack of good judgment and an act of utter folly to shove a vessel blindly into the ice without a coast to fall back upon. In closely following the Siberian shore, Nordenskiold, with comparative ease, accomplished the Northeast Passage, while Weyprecht and Payer actually sacrificed the Tegethoff in consequence of attempting to push through the ice. As another warning example the fate of the Jeannette can fairly be mentioned.

§ *Loc. cit.*, p. 556.

Although these statements do not agree in every respect, they still tend to prove that Budington felt reluctant to proceed northward. That those witnesses who testified to having seen a water-sky, frost-smoke, or open water to the northward were correct, may perhaps be proved by the following table, containing some meteorological observations made on board the Polaris during the 30th and 31st of August.

Date.	Time.	Psychrometer.		Relative Humidity.	Wind.			State of Weather.
		Dry Bulb.	Wet Bulb.		Direction.	Velocity in Miles.	Distance in 24 hours.	
1871.	h.			p. c.				
Aug. 30	7	30.8°	29.8°	89.2	N.	12	371.0	Fog.
	4	29.2	28.2	88.8	N.	7		Fog.
	11	31.0	29.0	78.8	N.	7		Fog.
" 31	7	28.8	28.0	91.0	NW.	1	113.0	Fog.
	4	29.2	28.5	92.2	NW.	8		Fog.
	11	28.8	28.0	91.0	0	0		Fog.

Unfortunately, ten observations out of the sixteen made during this period were lost, but the above table speaks for itself. It shows clearly that during six hours of fog the wind was in five instances northerly, and that the air was almost saturated with moisture. That these moist northerly winds, accompanied by fog, which the Polaris experienced while steaming through Smith Sound, must have passed over a sea not entirely covered by ice, can scarcely be doubted.

I am unable to say whether Mr. Budington took these conditions into account, but I state here without any hesitancy that he could not have had more than the most superficial knowledge of the condition and character of the ice at the time. A satisfactory survey of the surroundings can be obtained only from the crow's-nest, but Budington never considered it worth while to ascend the Jacob's ladder. To this, every impartial survivor of the Polaris expedition will testify. According to Budington's judgment it was quite impossible to attain a higher latitude. And Hall, not being a sailor himself, was weak enough to yield to Budington's views. He did this, however, with much reluctance.

About two o'clock on the afternoon of the 31st of August the vessel was headed to the westward to cross the channel, subsequently named by Hall Robeson Channel. The dreary old fog set in anew, and at half-past five we were compelled once more to make fast to a

floe. When the ice opened (at 9h. 25m.) on the morning of September 1st, the vessel was again under way; but at ten o'clock she was moored once more to a floe about five feet above water, and probably not less than five miles in length. During the night an ice-cover, about a quarter of an inch thick, had formed on the narrow leads around the vessel, which now rose and sank under the influence of a gentle swell. A light northerly breeze set the floes and hummocks slowly towards the north, and the northern horizon was hidden by dark frost-smoke.

About two o'clock in the afternoon, Hall and Chester walked across the floe to which the Polaris was moored, attempting to reach the coast of Grinnell Land. They had hardly left when the ice about the vessel began to move, pressing hard against her starboard side and causing her to heel over considerably. The pressure lasted, however, only forty minutes. When Hall and Chester returned, about five o'clock, everything was quiet. They had approached the coast within four miles, and from the summit of a high hummock had noticed a small bay, which, in their opinion, would have afforded a good anchorage. Unfortunately, they had not arranged for signalling the results of their observations, or we might have steamed around the floe to the place. Now it was too late; for Chester, who went to the crow's-nest, reported the leads to have closed.

The ice remained quiet until eight o'clock, when the pressure began again, and became much stronger than it had been six hours before. It was evidently due to the turning tide, and the movement of the ice was accelerated by a strong easterly wind. The vessel, anchored to the floe with hawsers fore and aft, suffered a severe nipping; so great was the pressure that the lines bent to the ice-anchors parted under the strain. A large berg bore down upon her, piling up the ice in wild confusion, and at half-past ten it began to hummock under her bow and probably under her keel.

Hall at once gave orders to take stores and provisions on deck. About eleven the force of the pressure diminished, and half an hour past midnight the Polaris was released from the icy grasp of the fields. This peace, however, was only of short duration, and at half-past two we were troubled even more than before. The wind freshened, and a heavy fog set in, entirely concealing the eastern coast, while the shore of Grinnell Land appeared only in dim outline. Shortly afterward it was hidden likewise. Between nine and ten on the morning of the 2d of September the pressure became heavier, and a portion of the stores and provisions was landed on the ice-field on the starboard side of the vessel. Towards 3 P. M. the ice slackened,

and two snow-buntings alighted on the rigging; the meteorological observations, which had been interrupted, were commenced again. At about 4 o'clock on the morning of the 4th, we had the first glimpse of the sun for six days, but its limb was not sufficiently well defined to measure the altitude. Since leaving Tassiussak only four observations for latitude had been obtained, and the last one, taken on the 29th of August, which was not very reliable, had placed us in latitude 81° 20′ N. After the fog had been entirely dispersed, we noticed that we had drifted a considerable distance towards the south. The highest latitude reached was 82° 26′, according to the indication of the patent logs, or 82° 16′, if we make due allowance for the current, the velocity of which, however, could not be accurately determined. Never before had any vessel attained so high a latitude.*

Towards nine in the morning some open leads formed in the vicinity of the vessel, and the provisions were taken back on board. This was accomplished in about three hours; but when the vessel was ready to start we were troubled by dense fog, which delayed her till 8.45 P. M. Steering for the east coast of the newly-discovered channel, the Polaris found herself close to the shore, and Hall started in a boat to look for an anchorage. He landed, and, unfolding the flag, he took possession of the country in the name of God and the President of the United States. Upon his return, the vessel anchored in ten fathoms of water, about 300 yards from the shelving beach. The sun had ceased to be circumpolar, but when we came to anchor it was still perfectly light. Two Arctic fulmars, the winged heralds of open water, came close to the vessel; we had not seen any of these birds since we had left Tassiussak, and a long time elapsed before we saw them again.

After we had breakfasted, Chester went to the crow's-nest and reported water to the northward. Hall consulted with his sailing-master, his first mate, and assistant navigator as to the practicability of getting farther north in the vessel. "*Captain Budington, with an oath, said he would be damned if she should move from there. He*

* The Polaris can probably claim to have reached a higher latitude than lat. 82° 26′ N.; another revision of the day's work results in lat. 82° 29′ N., but positions obtained by dead reckoning cannot lay much claim to accuracy. On a subsequent occasion (June 30th, 1872), Mr. Meyer observed the lower culmination of the sun at Repulse Harbor, which gave lat. 82° 9′ N., but probably the Polaris was more than nine miles to the northward of the small bight when she reached her highest latitude. Latitude 82° 24′, the mean of the three different observations, is probably more accurate.

walked off, and Captain Hall followed him, and they had some conversation together." *

Both Chester and Tyson, who had had a great deal of experience in the ice, tried to convince the commander that a higher latitude could be reached, as may be inferred from their respective testimonies; but Hall, influenced by the sailing-master, gave orders to land the stores and provisions. The honor of the flag, the success of the expedition, were thereby sacrificed to the whim of a single individual, whose moral courage, at his best, was mostly at low ebb.

The anchorage of the Polaris was subsequently named by Hall, Thank God Harbor, and a large iceberg to seaward, which was supposed to protect the vessel from the pressure of the floes, received the high-sounding name of Providence-berg. Without much delay the observatory was erected on the most suitable spot we could find, at an altitude of 34 feet above the sea-level; and Hall, assisted by Bryan and Meyer, commenced to make a survey of the surrounding country, which consisted of a gray, slaty limestone belonging to the upper Silurian, as was shown by the various fossil corals it contained.†

Shortly afterwards, Eskimo Joe, while on one of his hunting expeditions, discovered tracks of musk oxen. His report filled us with pleasure and surprise, for we never expected to find this animal alive in these high latitudes, although some sub-fossil specimens had been discovered by Kane near Van Rennselaer Harbor, and the German Expedition under Koldewey had killed some in East Greenland. Chester and myself, accompanied by the two natives, were sent out on a sledge journey to reconnoitre the interior of the country and to look for this rare game. We left the vessel on the 18th of September, and returned on the 23d with one young female animal, the only specimen seen, although we had noticed numerous tracks. From the top of a mountain about 2000 feet high, subsequently named Mount Chester, we had a good view of the country and could study its topography. We could see the terminus of Newman's Bay and the ice-cap cover-

* Report, p. 299. In the "Narrative" we read on p. 105: "But not relying wholly upon his own judgment and experience in ice-navigation, Hall again consulted, separately, his sailing-master, assistant navigator, and mate, as to the practicability of attempting to get farther north on the vessel. He came to the conclusion that such an attempt would be injudicious."

† In the "Narrative," p. 331, these inoffensive animals are degraded to plants, as may be inferred from the following sentence, which is one of the few in the book touching upon scientific subjects: "*They were the only vegetable fossils that had been discovered by the expedition and were very fine specimens. They looked liked petrified pieces of sugar-cane or bamboo.*"

ing the greater part of the land, with the glaciers discharging in Petermann's Fjord, whose high precipitous cliffs we could trace for a long distance.

After the return of the first sledge-party Hall himself decided to undertake a journey to determine how far north the land on the east side of the channel extended. Accompanied by Chester, Joe, and Hans, he left with two sledges on the afternoon of the 12th of October. The party proceeded overland, and they reached lat. 82° 3′ N., long. 61° 20′ W. There on the high cliffs north of Cape Brevoort, Hall erected a cairn in which he deposited a dispatch addressed to the Secretary of the Navy, stating that "the mountainous land will not admit of our journey further north. * * From Cape Brevoort we can see land extending on the west side of the strait to the north 22° west, and distant about seventy miles, thus making land we discovered as far as latitude 83° 5′ north. There is appearance of land farther north, and extending more easterly than what I have just noted, but a peculiar dark nimbus cloud hanging over what seems may be land prevents my making a full determination."

Shortly after one o'clock in the afternoon of the 24th of October, the party was back on board the Polaris. Hall, who had been exposed to low temperatures, went to the warm cabin without taking off his heavy fur clothing, and drank a cup of hot coffee. Shortly afterwards, he had an attack of apoplexy, to which he succumbed at 3.25 on the morning of the 8th of November, after having shown for several days the most unmistakable signs of serious mental derangement. At eleven on the morning of the 10th he was buried, about a quarter of a mile south of the observatory.

It was not an easy task to reconcile the discoveries made by Kane and Hayes with those of the Polaris, and after Hall had seen from Cape Brevoort that the land on the west side stretched far to the northward, this question became even more complicated.

Kane, as mentioned before, used the observations of Morton to show the existence of an open Polar sea north of Kennedy Channel. Hayes, instead of contradicting the report of his predecessor, not only confirmed it, agreeing to all his views, but also arose as its ardent defender, publishing the narrative of his expedition under the title "*The Open Polar Sea*." Morton fancied he had seen this open Polar Sea from the northwest coast of Greenland, and Hayes claims to have observed it from the opposite coast, that is, from the east coast of Grinnell Land.

From page 349 of his book I quote the following passage:

"Suffice it here to say that all the evidences showed that I stood upon the shores of the Polar Basin, and that the broad ocean lay at my feet; that the land upon which I stood, culminating in the distant cape before me, was but a point of land projecting far into it, like the Ceverro Vostochnoi Noss of the opposite coast of Siberia; and that the little margin of ice which lined the shore was being steadily worn away; and within a month the whole sea would be free from ice, as I had seen the north water of Baffin Bay, interrupted only by a moving pack drifting to and fro at the will of the winds and currents." Hayes made these observations on the 19th of May, 1861, from a point that he locates in lat. 81° 35′ N., long. 70° 30′ W. He supposed that his radius of vision comprised sixty miles. Why then did he not see from Cape Lieber, the summit of which he claims to have climbed, the opposite coast discovered by the Polaris only a few miles to the eastward?

Whoever attempts to analyze critically the sledge-journey made by Hayes, and tries to compare the results obtained with the astronomical observations taken by Hayes while under way, will be puzzled by many contradictory statements not easily accounted for. His narrative shows that his most northerly camp was established on the 18th of May (p. 348), while, according to the scientific results of the expedition, the position of that very camp was determined astronomically on the day before.*

* *Physical Observations in the Arctic Seas*, by Isaac I. Hayes. Reduced and discussed, at the expense of the Smithsonian Institution, by Ch. A. Schott, Washington City, Smithsonian Institution, 1867, p. 20.

In consideration of the importance of the fact above mentioned, I herewith give the original observation and its reduction, with the resulting latitude.

Farthest Camp, Kennedy Channel.

Observations for latitude of camp, May 17th, 1861.

Meridian altitude of the sun. Dr. I. I. Hayes, observer.

	2 ☉		
Pocket sextant . . .	56°	52′	Temperature = + 22°.
Index correction . .	− 1	31	Barometer = 31.0 in. 53°, approximately.
			Approximate longitude, 4h. 35½m.
	55	21	
Altitude	27	40.5	
Refraction—par. . . .	—	1.8	
Semi-diameter . . .	+	15.8	
Maximum altitude . .	27	54.5	
δ at apparent noon . .	19	26.0	
ϕ	81	31.5.	

Which of these two statements ought to be accepted? There can be no possible doubt as to the day when Hayes reached his highest latitude. The record that he deposited in the cairn at Cape Lieber is dated May 19th, and this is confirmed on page 351 of the narrative. I quote besides the following passage from the same page, where he states, "We arrived there after a tedious march of 46 days duration." Page 295 shows that the explorers left Port Foulke on the evening of the 3d of April; consequently a march of 46 days would give the date as the 19th of May.

So much for the narrative. But now what do we learn from the astronomical observations? There is no observation on record for position on the 19th of May, but, according to a meridian altitude of the sun, the result of which was latitude 81° 31′ 5″ N., Hayes estimated the position of his most northerly point to be in latitude 81° 35′ N. The next observation for latitude was obtained on the 20th of May,* or the day after Hayes had reached his extreme northerly point. The computation given below locates this in latitude 79° 58.5′ N.

The difference of latitude between Cape Lieber and Camp Leidy amounts to 1° 36.5′. If Hayes could have travelled in a straight line, this day's march would have represented a distance of 96½ nautical miles. But owing to the condition of the ice he could not travel in a straight line, and had to follow the sinuosities of the coast. If we measure his route on Schott's map, accompanying the "*Physical Observations*," we get a distance of 132 nautical miles; and a measurement

* *Loc. cit.* On page 20 we find the following observation:

Camp Leidy, Smith Sound.

Observations for latitude of camp, May 20th, 1861.

Meridian altitude of the sun. Dr. I. I. Hayes, observer.

	2 ⊙	
Pocket sextant . . .	61° 14′	Temperature = + 22° (about).
Index correction . .	— 1 30	Barometer = 29.7 in. at 52°, approximately.
	59 44	Approximate longitude, 4h. 44m.
Altitude	29 52.0	
Refraction—par. . .	— 1.7	
Semi-diameter . . .	+ 15.8	
Maximum altitude . .	30 06.1	
δ at apparent noon . .	20 04.6	
	φ 79 58.5.	

on Hayes' own chart (*The Open Polar Sea*, p. 1) would still considerably increase that number. Supposing then that no mistake occurred, Hayes would have travelled at least 132 miles between the 19th and 20th of May.

Page 347 of the narrative contains the following passage: "With the view of ascertaining how far this course was likely to carry us from a direct line, I walked, while the dogs were resting, a few miles along the shore until I could see the head of the bay, distant not less than twenty miles. To make this long détour would occupy at least two, if not three days,—an undertaking not justified by the state of our provisions." To account for this great distance is almost impossible; for Hayes made the above statement on the 18th of May, the day before he reached his extreme northern latitude. The route, therefore, could not have been anything but tempting.

In default of the volume containing the astronomical observations made by Hayes during his sledge expedition, it would be next to impossible to determine the positions of his camps during the second week of May. His narrative throws but little light on this subject, and those paragraphs pretending to give exact statements are in direct contradiction to corresponding passages of the scientific publication.

Hayes unfortunately depended solely upon meridian altitudes of the sun to determine his latitudes, instead of measuring circum-meridian altitudes. If he had adopted the latter method, many of the doubts now resting on an enterprise that cannot but command our highest admiration might be removed. Certain differences could be explained by the supposition that Hayes accepted as meridian altitude an altitude of the sun measured before or after its culmination. In this case, considering the lower altitude of the sun, we would obtain a higher latitude, but at the same time the latitudes determined on the return journey would also be too high.

If any one would study the geography of the Smith Sound region as established by our own observations, and the narratives of Kane and Hayes, without referring to the above-mentioned geographical positions determined by Hayes, the conclusion would be that this explorer, during his sledge expedition, overestimated all the distances, and that he actually did not cross the 80th parallel. A critical comparison of the charts only confirms this supposition. Kennedy Channel is very narrow; it is barely possible to pass through it without seeing both shores. Hayes, however, claims to have seen only the west

coast, though the atmosphere was sufficiently clear for numerous observations for position.

I constructed a chart on a large scale, showing the surveys of Kane and Hayes in different colors. It is not within the compass of this paper to reproduce this chart, but I propose to give a synopsis of the results arrived at with regard to the coast of Grinnell Land north of the 80th parallel.

Hayes deviates but slightly from Kane. He carries the coast-line only a little more to the north, and represents the bays as somewhat deeper than they are represented by his predecessor. Maury Bay, the northern extremity of which Kane located in latitude 80°, Hayes located farther north; and Scoresby Bay received a similar treatment, while the geographical position of Carl Ritter Bay remained unchanged. Hayes marks two small bays between Cape Black and Lady Franklin Bay, not found on Kane's chart; and north of Cape Eugenie, in the same latitude as Kane's Cape Murchison, Hayes located two more bays, hitherto not noticed.

In comparing the chart in Hayes' narrative with that in the *Physical Observations*, it requires considerable study to realize that both represent the same coasts. For the sake of brevity, I will designate the chart in the narrative as No. 1, and that in the *Physical Observations* as No. 2. In No. 1 the mouth of Kennedy Channel is 85 miles wide, almost twice as wide as in No. 2, where it corresponds with Kane's survey, which is the more correct. Although Hayes never sighted the east coast of the channel north of Humboldt Glacier, he made various changes in its representations in chart No. 1, thus producing a perfect caricature of that portion of Greenland. He furthermore shifts the coast-line near Cape Constitution more than 20 miles to the eastward. In No. 1, an island is represented in Carl Ritter Bay, and in Lady Franklin Bay we perceive even two islands not represented in No. 2. In place of the extensive Petermann Bay, in No. 1, we find in No. 2 the insignificant Wrangell Bay, and Wrangell Bay in No. 1 is named Lincoln Bay in No. 2.

I content myself with mentioning only the most apparent mistakes. The discoveries of Hayes and their graphic representation would appear in a still more unfavorable light if we were to base our criticisms upon the facts that the outlines of the coast of Grinnell Land north of the 80th parallel are almost identical on the charts of Kane and Hayes; that Kane's survey of that coast is based solely on cross-bearings taken from the coast of Greenland, and that the coast of Greenland, as

represented by Kane, is located too far to the north. In changing the position of the base-line, those points intersected from various points of the base-line would necessarily also have to be changed in bearing and position. Where Hayes claimed to have seen his "Open Polar Sea," the Polaris had discovered land—land bordering a channel so narrow that the coast of Grinnell Land, even under unfavorable conditions, could easily be seen in the dim light of the moon from the anchorage of the vessel.

The cairn which Hayes states that he erected on Cape Lieber could not be found by the English expedition under Sir George Nares, as we shall see hereafter, and Greely also looked for it in vain. The only discovery Hayes might rightfully claim is that of the United States Sound, the existence of which had already been supposed by Kane.* Mr. Chas. A. Schott, Assistant of the United States Coast Survey, who discussed the physical observations of Kane and Hayes, informed me that Kane on his manuscript chart had actually left the sound open, and that he closed it only after the map had been redrawn and newly projected by Mr. Schott.

After Hall's untimely death, Mr. Budington and the writer held a consultation, according to the following paragraph of the instructions of the Navy Department:

"You will give special written directions to the sailing and ice-master of the expedition, Mr. S. O. Budington, and to the chief of the scientific department, Dr. E. Bessels, that, in case of your death or disability — a contingency we sincerely trust may not arise — they shall consult as to the propriety and manner of carrying into further effect the foregoing instructions, which I here urge must, if possible, be done. The result of their consultations and the reasons therefor must be put in writing and kept as a part of the records of the expedition. In any event, however, Mr. Budington shall, in case of your death or disability, continue as the sailing and ice-master, and control the movements of the vessel; and Dr. Bessels shall in such case continue as chief of the scientific department, directing all sledge-journeys and scientific operations."

The regular scientific observations had been fairly under way; the transit instrument had been set up; and the tide gauge and meteorological observations, which had been made every three hours before entering winter-quarters, were made every hour. Subsequently,

*Kane, Arctic Explorations, vol. I., p. 256.

the pendulum experiments were commenced, and also the magnetic observations.

On the 21st of November, during a heavy northeast gale, accompanied by a blinding snowstorm, the vessel broke out and went adrift. With severe shocks she was repeatedly driven against the floating masses of ice, but after several desperate efforts she came to anchor again, having brought up against the iceberg that Hall had named Providence Berg, and which actually saved her from being carried seaward. After she was again frozen in, a gale from the southwest, which caused great damage at the observatory and at the snow huts containing the magnetic instruments, set the ice once more in motion. The Providence Berg, our only protection, was forced inshore, shoving the vessel before it. If the ice on the lee side had been stronger, the Polaris would have been cut through or thrown on her beam-ends. Afterwards, the berg, which had been split in two, grounded and was at the point of turning over; and when the tide fell still more, the stern of the vessel was some four feet below her bow. Not until the time of high water did she come again on an even keel; but she leaned against the berg with her bow perched upon its tongue, which was under water, and she continued to do so, listing in the most disagreeable manner at low tide. Along the margins of the old floes close by, the hummocks were piled up to the height of about thirty feet, and under the constant pressure the berg began to crumble.

Christmas drew nigh and was duly celebrated, and the new year approached, but the position of the vessel remained almost unchanged. The sea in the channel was open; we could hear the sound of the waves breaking against the ice, and the grinding noise of the floes could not for a moment be mistaken. The propeller and rudder of the vessel were still buried under the piled-up hummocks, and there was great danger that her bow would be wrenched and broken off. Several attempts to free her by blasting proved fruitless.

During the course of the winter the carpenter had made a number of sledges after different patterns, to be used in the spring campaign, provided it should be possible to undertake the proposed sledge-journeys. The increasing twilight now enabled us to obtain a better view of the character and condition of the ice. The sea was covered by high, countless hummocks, with scarcely any level spots between them, and these rugged masses were almost in constant motion. As a rule, the northerly winds produced open water, which

frequently extended to the vicinity of the vessel, while the winds from the opposite direction had a tendency to pack the ice. As the further operations of the expedition were largely dependent on the condition of the ice, the coming changes were closely watched from the top of a neighboring cape. Almost daily the man on the lookout reported open water.

On the 28th of February the sun reappeared after an absence of 132 days; on the same day Joe saw the first dovekies, and on the 14th of March the first snow-bunting was noticed. As we could not reasonably expect to make any progress to the northward in sledges, a small party proceeded to the south to reach Cape Constitution in order to fix its position and to explore the coast. It seemed certain that the remaining work of the expedition would have to be done either by the vessel or by boats. The party, which was subsequently joined by Hans, consisted of Mr. Bryan, Eskimo Joe, and myself; we left the vessel on the 27th of March, and returned on the 7th of April, after having partly explored Petermann's Fjord, and made a survey of the coast. Owing to the ruggedness of the ice and the intervening open water, Cape Constitution could not be reached. Afterwards, several other sledge-journeys of shorter duration were undertaken by Chester, Tyson, Bryan, and Meyer, for the purpose of making surveys and for obtaining game. The deck of the vessel was cleared of ice and snow, and the preparations for the boat-journey to the north were gradually completed.

On the 24th of May the engineers discovered some three feet of water in the bilge; the vessel was leaking; the pumps were tried, but without effect, for they were frozen. Not until the next day was she freed from water, which soon returned with an increase. The leak could not be discovered before the 3d of June. When found, it proved to be on the starboard side of the bow, near the stem, below the 6-foot mark. How badly the stem (which had been cracked) was injured, could not be ascertained, but in the course of the day a corresponding crack was discovered on the port side; and as this side was under water, even at low tide, there was no possibility of stopping the leak. The iron sheathing on the starboard side, which had been removed to caulk the crack and lead it over, was replaced and the pumps had to be constantly worked.

Notwithstanding all these difficulties, two whale-boats with the necessary provisions had been sledged to Cape Lupton, to take advantage of the first opportunity to proceed northward and to try to reach as high a latitude as possible. Chester, in command of one,

had started on the 8th of June, and had lost her on the morning of the 9th, amidst the grinding ice. He returned on board to get the portable Hegelman canvas-boat in readiness to renew his attempt. On the afternoon of the 10th, Tyson, with his crew and myself, left in the George Robeson, following the various open leads, and reached Newman's Bay in the course of the evening, when we were stopped by ice. The boat was hauled up and we camped. The ice to the northward was packed solid and there was no prospect of making any headway. In the course of the evening of the 15th we were joined by Chester, who once more had had a sore time. He had been beset and his boat had drifted to the south, but both he and his crew were in the best of health and full of courage and enterprise. We waited for open water, but our hopes and expectations were in vain. The ice drifted constantly to the south, except occasionally during the time of the spring tides, when a slow motion in the opposite direction could be noticed. Our sleeping-bags, notwithstanding the rubber blankets that formed the flooring of our tents, were saturated with moisture; to keep dry feet was simply impossible; Chester and his crew partook only of one warm meal daily. When the sky was clear, a dark cloud north of Cape Henry could constantly be noticed; this cloud changed its position so little that the tangents we had measured from our camping-place to its eastern and western extremities hardly ever varied by more than a few degrees. The apparent stability of the cloud finally led us to the supposition that it concealed a distant coast, to reach which was one of our most ardent desires. Towards two o'clock on the morning of the 29th, Hans suddenly arrived with a message from Budington, in which he stated that the condition of the vessel was at least a critical one, and that the boat-parties should come on board without delay. Hans was tired out. After he had rested for twelve hours, I accompanied him on board; we proceeded overland and reached the vessel after a march of thirty-nine consecutive hours. We had attempted to make a short cut by following one of the ravines, and finally we were compelled rigidly to follow its course, as it was wholly impossible to climb the perpendicular cliffs. Almost at the same time that I left with Hans, Mr. Meyer started to the northward and, on the 1st of July, reached the shore of Repulse Harbor, where he obtained an observation for latitude. Sorely snowblind, he returned to the camp, without having seen a trace of open water to the northward.

The condition of the Polaris was indeed a critical one; but, neverthe-

less, Budington had attempted twice to penetrate to the northward. In both instances he was stopped by heavy ice. The navigable season had evidently not yet commenced, and more than once the vessel was in danger of being lost. Tyson with the last of his crew returned on the 8th of July, and Chester came back on the 23d, after having made an attempt to return by water; but both boats had to be abandoned.

On the first of August there was sufficient coal left for only six days steaming; the pumps had to be worked constantly, and Budington considered it his imperative duty to start south as soon as an opportunity should offer; but the sea to the north was still blocked. Even during the summer the formation of young ice had seldom ceased. As there was not much chance to make an early start, two of the men obtained permission on the 5th to proceed to Newman's Bay in order to get some of the instruments that had been left there in the boats. They returned early in the morning of the 9th and reported that they had seen high land in the direction where we had constantly noticed the dark cloud from our camp. This land was subsequently named President's Land. While the two men were on the summit of Cape Brevoort, the refraction seems to have been very great; for, Hermann Siemens, one of the two, stated that Cape Union appeared so near that he might have been tempted to throw a stone at it. Shortly after the return of the men, Mr. Meyer, accompanied by one of the sailors, also proceeded to Newman's Bay; but it was misty, and the high cliffs seen by Siemens and Krueger were not visible.

Hans was now sent daily to Cape Lupton to report on the condition of the ice towards the south. On the 12th of August there was considerable open water in that direction and the vessel bore up for home. The observatory had been filled with stores and was well secured. At half-past four in the evening we left the anchorage and steered south, following the various leads. Towards midnight we reached the entrance of Petermann Fjord. From there Cape Union was the most northerly land visible to the westward, and the low shores of Polaris Bay had sunk below the horizon; while an isolated mountain, named by Hall, Inland Island, which in its character and outline vividly reminds one of Heligoland, appeared like an island between Polaris Promontory and the southern mountains. The high land north of Polaris Bay appeared isolated too, when viewed from the deck of the vessel. Meanwhile, the ice was closely packed, but by dint of labor we succeeded in reaching the more open water towards five o'clock on the morning of the 13th. Favored by a good

breeze, we proceeded under steam and sail until we were stopped, at about nine o'clock, by impenetrable pack which compelled us to moor the vessel to one of the floes. The ship, following the motion of the ice, drifted slowly towards the south, and when at about eleven a lead opened, she took advantage of it; but her progress was soon stopped. In the course of an hour we hardly accomplished a mile, and had to anchor once more at a heavy field. On the morning of the 14th several fruitless attempts were made to break through the pack, but about noon a narrow channel opened, which enabled us to get to Franklin Island, which was passed at a distance of three miles. Reaching its southwestern point, we sighted Cape Constitution and the gray cliffs of the John Brown Coast, of massive Silurian limestone. Steaming south, the solid pack was met with again about eleven in the evening; a set of circum-meridian altitudes of the sun placed us in latitude 80° 02′ N. Soon afterwards, the ice closed upon us, but from the crow's-nest some open water to the west and south became visible. Up to noon of the 15th the vessel was in a perfectly helpless position; then we succeeded in advancing a few miles to the westward, but were soon again compelled to make fast to a floe. All our attempts during the 16th to reach the open water were futile; we were fairly beset, and the vessel continued to drift.

As the more important details of the drift are to be considered hereafter, we shall not dwell upon them any longer at present. Towards the latter part of September we were convinced that we should have to winter in the pack, and the necessary preparations were commenced without delay. The leak of the vessel gave more and more trouble, and almost nine hundred pounds of coal were used daily to work the pumps; to stop the leak many plans were devised and tried, but all without the slightest success. A large quantity of stores and provisions were therefore landed on the strongest part of the ice-floe to which the Polaris was secured, and, under the supervision of Tyson, the men began to build a house of old timber and sails to serve as a place of refuge in case of emergency.

The last astronomical observation made to determine the rate of drift of the vessel was obtained on the 12th of October, and placed her in latitude 78° 28′ N.; she was then close to the coast of Greenland; the other data on record are not sufficiently accurate to be considered. It considerably increased our uneasiness that on the 14th of October the vessel began to drift more rapidly to the southwest; in case she drifted out of the sound it was almost a certainty that she

would get in the North Water, where destruction seemed unavoidable. The floe to which she was moored was turning, and at times made a complete revolution. Far to the southeast, Northumberland Island was now in sight, and towards evening a stiff breeze from the same quarter began to blow, steadily increasing in velocity. At 5 o'clock on the morning of the 15th we experienced an unusually heavy snow-fall, which lasted three hours. After it had stopped snowing, it blew half a gale, which continued all day, veering through south to south-west, and filling the air with flying snow to such an extent that it was next to impossible to see more than half a ship's length in any direction.

About six in the evening the watch reported that the ice at the stern of the vessel was separating; all hands rushed on deck, and it was discovered that meanwhile open water had formed on the starboard side. She was secured to the floe by an extra hawser over the stern, and preparations were made to abandon her. The massive field which had moved off her starboard side now suddenly came back, exerting such a heavy pressure that the smaller masses of ice were piled up to the height of the rail; a few minutes later she was raised and thrown over on her port side. Under these conditions the floe offered more security than the vessel, which received such a severe nip that her timbers cracked with loud reports and her sides seemed to give way. The night was pitch dark and the snow was drifting before the gale. One of the firemen rushed on deck and reported that the ice had penetrated her sides. The order to land the coal and provisions on the field was carried out with surprising rapidity. Instinctively every one seized what lay nearest to him and placed it on the ice. Most of our valuable collections and the greater part of the records of the expedition were landed. The two remaining boats and the scow had been lowered and carried to the strongest portion of the floe, where the two Eskimo women with their children had taken refuge.

Suddenly the ice-anchors lost their hold, the vessel righted herself and drifted with increasing velocity away from the field. For a few moments the air became clear and the light of the full moon shone on a scene of the wildest confusion and terror. The solid field was split in various directions; we could see portions of the provisions, some afloat and some sinking in the cracks; while many of the crew, rendered desperate by the situation, attempted by jumping to reach larger and safer pieces of ice. Then the moon was hidden again by clouds and we were surrounded by the darkness as before.

The vessel was filling fast, and the little bilge-pump that had been kept going could no longer be made to suck. By burning some of the cabin-doors and parts of the rigging, the engineers succeeded in getting up steam in the little boiler; but the danger that the fire would be extinguished by the rapidly rising water was so great that those on board the vessel did not expect her to float for another hour. The three remaining boats were on the floe, and the masses of ice passing by the vessel during her drift were too small to afford any security. The crew was perfectly helpless, but finally the steam pump gained on the leak, and at daybreak we found ourselves some five miles off the coast near Lifeboat Cove. Chester went to the crow's-nest to look out for the missing nineteen; he examined the ice in the sound with our best spy-glass, but did not see any traces of human beings. It was the opinion of all that our poor comrades had perished during the struggle; but every one feared to express his opinion. There was now nothing left but to run the vessel on shore, which was accomplished with great difficulty. Shortly before noon, when the sun for the last time was visible over the rugged hills, the vessel was beached and secured with heavy hawsers to some grounded hummocks, about 400 yards from the shore. An examination showed that the whole stem below the six-foot mark was broken off, and that the few planks still attached were bent back to the port side.

Preparations were immediately made to land our few remaining stores. The dismantling of the vessel and the building of a house on shore were entrusted to Chester, who, with his versatility of genius, accomplished the task in a remarkably short time. Some of the Itah Eskimos had come to visit us, and they proved valuable assistants. On the 24th of October we were comfortably housed, the engineers let the steam go down, and the wreck rapidly filled.

The scientific observations, which for a time had necessarily been interrupted, were once more taken up, as far as our instrumental means permitted. A small observatory was erected for the transit, and we continued the hourly meteorological observations.

On the 2d of March the sun reappeared, and Chester had already commenced to trim the material for building two boats, which were finished with great difficulty and with the most primitive means on the 17th of May. An attempt of the writer to reach Polaris Bay on dog-sledges was frustrated by the obstinacy and indolence of the native drivers, but another trip to Foulke Fjord, for the purpose of studying the character of the inland ice, was successfully carried out.

Mr. Bryan had been at Van Rensselaer Harbor and at the winter quarters of Hayes to obtain observations for time, and the crew made various hunting expeditions, which, however, did not yield much game. On the 31st of May the meteorological observations were discontinued; our scientific work had now come to a close. The valuable instruments, with a document containing a brief history of the expedition and the plan for our proposed escape, were securely cached in a cairn on the highest point of the peninsula, where Polaris House had been erected.

Early on the morning of the 3d of June the two boats left; one, commanded by Budington, the other, by Chester; only eight pounds of baggage were allowed to each man. Most of the collections saved from the wreck had to be left behind; we carried only our records, one box-chronometer, two sextants, the standard barometer, and thermometers, to verify our observations, and a complete set of meteorological instruments to be used during the voyage, the particulars of which I shall not here mention. The condition of the ice met with during the passage will be told hereafter. It suffices to state that the party, consisting of fourteen persons, was picked up in latitude 75° 38′ N., longitude 65° 35′ W., shortly before midnight of the 23d of June, by the Ravenscraig, a whaler of Kirkcaldy, Scotland, commanded by Captain William Allen, who welcomed us with the warm-heartedness of a true sailor.

Here we learned that our missing companions, Tyson and Meyer, the men, women, and children, had all been picked up near the coast of Labrador in latitude 53° 35′ N. by the Tigress, a sealing vessel from Newfoundland. They had spent 196 days on treacherous ice-floes, living in snow-huts, constantly drifting southward, suffering the pangs of hunger and threatened with a threefold death; but fortunately there was no loss of life. The events of this unparalleled drift of more than 1800 miles are still too fresh in our memory to be dwelt upon.

While we were on board of the Ravenscraig, which was fairly beset in the ice of Melville Bay when her generous captain offered us a passage, a naval expedition, consisting of the ships Tigress and Juniata, commanded by Commanders Greer and Braine, was about to be dispatched by the Navy Department to bring us relief. At Lifeboat Cove the commander of the Tigress found our deserted hut, without discovering, however, the cache with our documents; but he was informed by the Eskimos that we had started south in boats; and then he continued his search in that direction.

After the Ravenscraig had been liberated, she stood over for Lancaster Sound, which she entered early in the morning of the 6th of July. On the 7th, a sail was sighted, and on approach it proved to be the whaler Arctic from Dundee, commanded by William Adams. The Ravenscraig being short of provisions, Mr. Chester, the engineer, four of the men, and myself were transferred on board of the Arctic, where we found Commander A. Markham, R. N., as passenger. We accompanied our gallant skipper on his whaling cruise, which led us in the close vicinity of the magnetic pole, and in steaming out of Lancaster Sound on our way home we picked up four of those of our party who had been left on board of the Ravenscraig. Three others had meanwhile been transferred on board of another whaler. On the 13th of November the last member of the expedition landed safely in New York, and after the Tigress, which had been cruising in search of us till the 16th of October, had also returned to the United States, the whole enterprise had passed into history.

Some of the more important discoveries of the expedition will be mentioned hereafter, and in the course of this discussion we shall also see that those of the crew of the Polaris, who, after the return of the party, made the statement that if Hall had lived through the winter a much higher latitude by sledges might have been reached, were somewhat in error.

While different European nations had been diligently exploring the frozen North, England could not be induced to participate in this noble enterprise. Since the return of the British squadron sent out in search of Franklin and his missing party, nothing whatever had been done by the crown in the cause of Arctic exploration, notwithstanding the various earnest appeals made by scientific corporations, like the Royal Society, and by private individuals.

Encouraged by the success of the Polaris in reaching a high latitude, the Government, in 1875, finally decided to send out an expedition consisting of two vessels under Captain George Nares, the distinguished commander of the Challenger, in order to attempt to reach the North Pole via Smith Sound. The Alert and Discovery, specially built for ice navigation, were selected from the English whaling fleet, and a transport, the Valorous, was ordered to accompany the vessels as far as Disco. Captain Nares was in command of the Alert, while Captain H. F. Stephenson commanded the Discovery; the former, having a complement of sixty-one officers and men, the latter, one of fifty-nine. They

left England in the afternoon of May 29, 1875, and made various stops at some of the Danish settlements to procure the necessary dogs and stores, besides two natives, one of whom was Hans, who had taken part in every exploring expedition to Smith Sound.

The Alert, with the Discovery in tow, finally left Upernivik on the evening of July 22d. After several delays, caused by fog and dangers, the Brown Islands were passed by 4 P. M. on the next day, with a sea perfectly clear of ice before the explorers. A high and steady barometer gave promise that the calm, hitherto experienced after a southeast wind, would probably last for some time. Captain Nares therefore concluded to deviate from the track ordinarily followed by whaling vessels to Cape York and to pass through the "Middle Ice." After a run of sixty miles from the Brown Islands on a west by north course, the pack, consisting of light, open sailing ice, was reached at half-past one on the following morning. The floes were at first not more than 250 yards in diameter, and very much decayed, splitting easily when struck. About 6 A. M., after an additional run of thirty miles through the ice, the latter became closer and heavier, the floes at the same time increasing in size. For fourteen hours, during a run of another sixty miles, the ice showed almost the same appearance; but at 3 P. M. on the 24th, when the channels of water became broader and more numerous, both vessels steered directly for Cape York, which was sighted at 9.30 on the morning of July 25th. One hour and thirty minutes later, about forty-five miles due south of that Cape, the dark "North Water" spread itself before the navigators, who had crossed the much-dreaded "Middle Ice" in but thirty-four hours.

In his official report to the Lords Commissioners of the Admiralty, Sir George Nares expresses the following opinion: "At the latter end of July, with an open season, indicated by the main pack not being met with nearer than fifty miles from the land, in about latitude 73° 20′ and a continuous calm, to allow the northerly running current on the Greenland shore and the southerly running one on the western side of Baffin Bay to open up the ice, I believe a passage can always be made by a steam-vessel; but, unless this favorable combination of circumstances is met with, so far as the scanty knowledge we at present possess enables us to judge, the passage must still be said to be doubtful."

Passages like that of the Alert and Discovery are, however, of rare occurrence; for, even under apparently favorable circumstances,

vessels in the attempt to push through the "Middle Ice" are in danger of getting beset, and of being imprisoned for months, like the Fox, in 1857 and '58, while commanded by Sir Leopold McClintock. On such occasions man is powerless. There is no possibility of saving the vessel, when entrapped in the pack, among floating and grounded icebergs; and an expedition may be wholly crippled even before reaching its basis of operations. If the season is not too far advanced, and if the explorer has sufficient time at his disposal, it will be found safer to follow the land-ice off the Greenland coast, where it is always more or less easy to cut a dock for the vessel, in order to protect her against the pressure of the heavy pack.

This course had been taken four years before by the Polaris, under the most enviable natural conditions; and, owing to the almost total absence of ice, she accomplished the transit of Melville Bay between the 24th and 25th of August in twenty hours and forty-five minutes from Tassiussak, while the Alert and Discovery needed seventy hours to make Cape York from the time of leaving Upernivik.

Near Cape York the Discovery on July 25 headed for the shore to communicate with the natives, while the Alert proceeded towards the Cary Islands, where she was to be rejoined by her consort. Many icebergs, partly aground, were met with off the Cape, arranged in lines that followed the trend of the coast towards Conical Rock and Cape Athol. The bergs, of which a great number had also been observed by the Polaris at the same locality, were less numerous in the offing, and Sir George feels inclined to attribute this fact to the existence of a southerly current, which he experienced the following day while on his passage to the Cary Islands. This group was reached by the Alert early in the morning of the 27th, where a depot of provisions to maintain sixty men for two months was placed on the north-easternmost island of the group. It was high water about 5 A. M. of the 27th. From midnight until 2 A. M. the set of the current was to the northward; at 3 A. M. it was setting towards the northeast, and from 4 to 6 A. M., when both vessels left, the set was southerly. Steaming to the eastward, meeting hardly any ice, except a few scattered bergs, they anchored at Port Foulke early on the morning of the 28th. Before the expedition left England, I wrote to Commander Markham to have a party landed at our old winter-quarters at Lifeboat Cove, and to search the cache we had made there, which the Tigress, strange to say, had failed to discover, and to take our pendulum on board and have it swung in connection with that which

the members of the expedition were about to use. While Captain Stephenson explored the head of Foulke Fjord, Sir George, in company with Markham, proceeded to the spot. "The cache was readily discovered, but contained nothing." It had evidently been pilfered by the natives shortly after we had left Polaris House, although none of the objects it contained could have been of the least service to the Eskimos. The party found, however, three skin boats, left on the shore and weighed down with stones, the smallest of which was afterwards taken for conveyance to Cape Sabine. As the Itah natives do not use any boats at the present time, I think it highly probable that these Umiaks belonged to some of the western Eskimos, then visiting the Itanese; an incident of rare occurrence.

The morning of the 29th found the Alert and her consort sailing across the sound for Cape Isabella, with a northerly wind and fine weather, which was followed by a blinding snowstorm when they reached the coast. On the outer spur of the granitic walls of the cape, 700 feet above sea-level, the explorers built a cairn, and at a lower elevation they deposited about 150 pounds of preserved beef and an empty cask, intended for the reception of any letters that might be brought by a vessel the next year. At 5 P. M., the wind having died away, they steamed to the northward for Cape Sabine. Scarcely twenty-four hours before, when viewed from the summit of Littleton Island, the sea seemed to be entirely free of ice; but now, about fifteen miles north of Cape Isabella, the battle with the pack already began. The ice consisted of large floes and broken fields; it surrounded the vessels, and extended as far north as could be seen from the crow's-nest. "From this date the progress was one endless and unceasing struggle with the ice; ever on the watch and never allowing a favorable opportunity to pass unheeded." In a little harbor, subsequently named Payer Harbor, the vessels were detained for three days, watching for an opening in the ice. On the southernmost of the neighboring islets a depot of 240 rations was made, and on the summit of the outer one the expedition left a cairn with a notice of their movements. The pack in the offing consisted of floes from five to six feet thick, occasionally intermixed with heavier floes, but all much decayed and honeycombed. After several hours of light westerly winds, the vessels were at last enabled to round Cape Sabine on the morning of the 4th of August. Bearing away to the westward, they steered up Hayes Sound, keeping close to the land, the grounded icebergs giving timely notice of shoal water. Very

heavy ice was piled some thirty feet high against the northern point of Cape Sabine. About noon the vessels opened a land-locked bay, named Alexander Harbor, and as the ice ahead was closely packed, they steered for the entrance and cast anchor. On the 5th of August, the strong tides, combined with a southwesterly wind, opened a channel to the northwest, and thereby a few miles were gained; but afterwards the vessels were helplessly beset. Twenty-four hours later they bored their way through the slackening ice and emerged into a space of open water.

The surveyors of the expedition soon discovered that the map of the west coast of the channel as drawn by Hayes was greatly in error. The two islands marked by him in the entrance of the sound bearing his name were found to be joined, as originally represented by Inglefield, and no inlet between Cape Camperdown and Cape Albert could be seen. The party of the Polaris wintering at Life-boat Cove had been informed by the Itah natives that Hayes Sound opened to the westward into a broad expanse of water, and they fully believed that statement, for the Eskimos are excellent topographers. Captain Nares is, however, of the opinion that it is landlocked, for the flood-tide came from the eastward, and the ebb or east-running tidal current was stronger than during the flood. On two occasions, however, the ice in the offing was setting to the eastward with the flood tide. The future will have to decide whether Ellesmere Land is separated from Grinnell Land or not.

After various narrow escapes, and after overcoming great and unexpected obstacles, the vessels on the 9th tried to round Cape Prescott, but had to make fast to a floe; Franklin Bay was still covered with smooth ice of one season's growth. During the two following days the weather was calm, with fog and light rain. From the summit of Lockyer Island, about 900 feet high, some open water could be discerned near Cape Victoria; but in the offing and in a northeasterly direction towards Cape Hawks the ice was closely packed. In the afternoon of the 12th it at last began to move slightly to the eastward, and the vessels made a new start, and at nine in the evening passed the imposing cliffs of Cape Hawks, where a boat was landed and a depot made similar to that left on the Cary group. On this occasion a party visited Washington Irving Island to erect a cairn, and were surprised to find the remains of an extremely old one. The stones were covered with lichens, and the structure could certainly not be attributed to Hayes. Again the vessels were greatly troubled by

ice, and blasting and cutting were necessary in order to form a dock; but on the 19th of August they were able to proceed, after having advanced not more than about ninety miles in three weeks. Cape Frazer was successfully rounded in the course of the evening, and Captain Nares could confirm that the northern and southern tidal waves actually meet within a few miles from the region which I had pointed out.* From the summit of Cape Barrow, leads of open water could be distinguished to the northward, partly covered by loose ice; and near Cape Constitution the sea was probably as open as at the time when Morton discovered his "Open Polar Sea." Early on the morning of the 20th of August, when the ice had slackened, the vessels left their moorings at the height of spring-tide. The commander was well aware that during the present tides this would be his last chance to proceed, without the help of strong westerly winds; he therefore bored his way through the pack for two miles. Cape Norton Shaw was rounded without difficulty, and Scoresby Bay was opened; but off Cape McClintock, while the vessels passed through a channel between two closing floes, they were badly jammed and barely escaped a severe nip. They succeeded, however, in reaching Cape Collinson, but then they were once more obliged to make fast to a floe, for the open water previously seen to the northward had

* Markham states on page 106 of "*The Great Frozen Sea*," that they "were able to confirm the observations made by Dr. Bessels of the Polaris relative to the meeting of two tides at or about this point. This fact materially strengthens the argument in favor of the insularity of Greenland, for it has been deduced from a series of tidal observations obtained by us, that the tide to the northward of Cape Frazer—that is, the tide in Kennedy and Robeson Channels—is undoubtedly the same as the North Atlantic one, and therefore flows along the northern coast of Greenland." My friend Markham, when he wrote this passage (and also Captain Nares), was evidently not aware that I had proved the insularity of Greenland by means of our own observations, long before the English expedition returned. A copy of the paper, published at Washington, on the 29th of February, 1876, was sent them to London, and taken with the rest of the mail to Smith Sound by Sir Allen Young, in the Pandora. The accompanying map, with the co-tidal lines, which is reprinted in Vol. I. of the Scientific Results, proves that I traced the course of the tidal wave around the north coast of Greenland to Polaris Bay. During our daily intercourse, while on board the Arctic, we conversed freely upon the subject, but I then considered the tidal wave of Polaris Bay to be of Pacific origin. When the results of the German expedition to East Greenland were published, and when I had consulted the literature on the subject, I was at once convinced of my error, and so stated without hesitation.

disappeared. Two hundred and forty rations were landed near the Cape; while this work was in progress, the current was observed to set more rapidly to the southward than had been previously noticed in the wider parts of the sound. Markham estimated its velocity at one and a half or two knots;* Sir George Nares states that during each flood-tide about five miles of ice drifted south, while during the four hours of the ebb it remained almost stationary. On the north side of each point of this shore the hummocks were piled up to a height of from 20 to 30 feet, but elsewhere hardly any signs of great pressure could be noticed.† After two futile attempts to push to the northward along the west coast, the commander finally decided to stand to the eastward. Several miles of closely packed ice had to be broken through before they reached the middle of the channel, where they found some open water; but then the wind commenced blowing so hard from the north that the vessels had to be worked to windward under fore-and-aft-sails, and the floes made short boards necessary. Notwithstanding all difficulties, they made good headway; but, on reaching Cape Morton on the morning of the 23d, they found a solid barrier of large fields and immense hummocks, stretching across Hall's Basin to the westward, and as far to the north as the eye could reach. While the Discovery landed two hundred and forty rations at Cape Morton, the Alert was taken to Bessels Bay, where in the evening she was joined by her consort. From the summit of Hannah Island it could be noticed that the loose ice met with in the channel was now drifting rapidly to the north before a strong southerly wind; this was not at all encouraging, for, the heavy pack blocking Hall's Basin was thereby constantly increased. It was low water at Bessels Bay at 10.40 P. M.; the ebb current had ceased to run 40 minutes before, and at 11 P. M. the flood current was setting in the bay with sufficient force to swing the ships broadside to the wind. Early on the morning of the 24th Captain Nares discovered from the summit of Cape Morton a lead to the westward, which was speedily followed, and after severe struggles with the ice at Cape Lieber, the explorers reached the north shore of Lady Franklin Bay, and were there greeted by a herd of nine startled musk oxen. The commander wisely decided to leave the Discovery in a snug little harbor, subsequently named after their vessel, and to proceed north in the Alert; the navigable season was rapidly drawing

* *The Great Frozen Sea*, p. 108.

† *Nature*, 1876, p. 29.

to a close, and after an excellent harbor had once been secured in a high latitude the success of the expedition seemed certain, even if the advance vessel should meet with an accident. Better measures could hardly have been taken; the retreat of the party, in case of emergency, was well covered by the various depots established on their way north and by the vessel about to be left at Discovery Harbor. To strengthen the force of the Alert and to keep up communication with her consort, one officer and seven of her men joined the advance vessel, which left Discovery Harbor on the morning of the 26th of August. Meanwhile the pack had set in, and the ship, trying to keep clear of the moving masses of ice, touched ground and hung for a short while. By lightening her, and lowering her boats, she was soon afloat again without having been damaged. In the course of the afternoon, a narrow lead opening, the vessel was able to proceed; but at Distant Cape the solid pack was met once more, stretching apparently across the strait, and the Alert came to a stop. During the following day a light northeast wind caused the ice constantly to move to the south, except during the time of the ebb-tide, when it either remained stationary or set slowly in a northerly direction, but not with sufficient velocity to open a passage. On the 28th the explorers succeeded in advancing fifteen miles, but in attempting to push through the pack, the rudder-head, which had already been badly sprung, became so much injured that the rudder was almost useless, and the vessel was secured to some grounded ice in a small bay to repair damages. Cape Beechy was easily rounded on the following day, but the vessel had a narrow escape afterwards in doubling Cape Henry VII. The ice had now assumed a wholly different character; some of the grounded masses were estimated to have a thickness of from eighty to one hundred feet. They were not of glacial origin, but had evidently been formed on the sea; still they looked like formidable icebergs; they combined the character of actual floes and real bergs, and were therefore named floe-bergs. After a depot of one thousand rations for spring travelling had been landed on the north side of Lincoln Bay, which had been reached on the 29th, the Alert, at time of high water on the following day, was enabled to proceed to the northward. A night of anxiety was spent in the moving pack, for the vessel had hardly entered a promising lane when she was enclosed by the ice; but she succeeded in struggling back to Lincoln Bay. On the morning of the 1st of September the ice opened along the mainland, and the commander, attempting to do his utmost,

ran to the northward before a strong gale, and about noon reached latitude 82° 24′ N., the highest latitude ever attained by any vessel. The ship had been running at the rate of at least nine knots; she tried to reach President's Land, reported by the Polaris, but near one o'clock she was suddenly stopped by an impenetrable pack. Finding that the ebb-tide was setting towards the northwest along the land, and that the ice moved towards the shore, the Alert, which meanwhile had been moored to some grounded pack near Cape Sheridan, was taken to a more secure place. There, in latitude 82° 25′ N., longitude 61° 30′ W., she was compelled to winter. Markham and Lieut. Pelham Aldrich had been sent out to examine a bay about eight miles to the westward, which promised to be a good harbor; but it was unapproachable on account of stranded ice. The anchorage of the Alert was fully as unsafe as that of the Polaris; her only protection consisted in a number of floe-bergs grounded at a distance of a couple of hundred yards from the shore, and more than once she was seriously imperilled. Fortunately, she experienced only one of those heavy northeast winds, which, as a rule during the winter months, form the greater percentage of winds in these high latitudes, and the rise and fall of the tide was very slight, amounting to not more than about 36 inches, even at time of spring-tide.

After the newly-formed ice was strong enough, the provisions and stores were dragged on shore, and several small sledge-parties and a boat were sent out to reconnoitre the coast and to establish a depot. The coast was found not to extend as far north as stated by the Polaris; and the land reported by two of the Polaris' crew and named President's Land could not be seen. "The sky being fairly clear," Captain Nares says, "this was the first day on which we were able to pronounce decidedly concerning the northern land reported to exist by the Polaris. After a constant watch and carefully noting the movements of the darkened patches, I was now with much reluctance forced to admit that no land existed to the northward for a very considerable distance. As seen through the light haze, the dark reflection of the sky above the detached pools of water in the offing, in strong contrast by the side of the light reflected from the close ice, which in a great measure is similar to the bright glare reflected from a large sand flat, creates a very decided appearance of land where there is a mirage; indeed sufficiently so as to deceive many of us when so anxiously expecting and hoping to see it."*

Nature, 1876, p. 33.

On page 383 I have stated the conditions under which this land was sighted. It was seen only by Hermann Siemens and Robert Krueger, two of our most trustworthy and experienced seamen; when Mr. Meyer proceeded to Newman's Bay a few days later, it was not visible, but he noticed the same dark land-cloud which I have described, and which apparently had not changed its position. The only explanation I can offer is that the men applied the variation of the compass in the wrong direction, and that the land they sighted is actually a portion of the high northern coast of Greenland; for, they told me at the time of their return that the distant land was so plain in view that they could discern its deep ravines and the various snow-patches covering the mountains. Unfortunately the surveys of the expedition were lost on the ice, and the chart drawn after the return of the party could therefore be only an approximation. Although this chart was published by the United States Hydrographic Office, this office can not be held responsible for its shortcomings; for, the details of the west coast—the work of the Secretary of the Navy and his friends—were put in at his own private office at the Navy Department, to the great disgust of the late Rear-Admiral Wyman, who at that time was the Hydrographer of the Navy. In consulting the brief diary of current events, which I am in the habit of keeping, I find how bitterly he complained one morning "to have to put such stuff on the chart." He was then coming from the old Navy Department, holding a proof of the chart rolled up in his hand. A comparison of the Polaris chart with the chart published by the Admiralty will easily convince us that the Army Fjord of the American chart can only be meant to represent the bay between Cape Sheridan and Cape Joseph Henry. Every member of the expedition was convinced at the time that the delineation of the coast of Grinnell Land as given by Hayes was utterly erroneous, but owing to the loss of our material we were not justified in making any alterations, although most of us were positive that Hayes could not have been north of the 80th parallel. To satisfy our doubts we longed to cross to Lady Franklin Bay to examine the cairn which Hayes claimed to have erected on Cape Lieber; but, the ice being in constant motion, we were unable to do so. The English expedition did not find it, and, as we shall subsequently see, Greely and his party also looked for it in vain. If there, it could not have escaped detection, even though partly demolished, for the traces of a cairn are not easily obliterated.

We shall now return to the Alert, whose commander, on the 25th

of September, sent Markham on a sledge journey to the north to establish a depot of provisions as far in advance to the northwestward as possible. Markham had three sledges, two of which were respectively commanded by Lieutenants Parr and May. Four days before his leaving the vessel, Lieutenant Aldrich had started with dog-sledges, provisioned for four days, to pioneer the road around Cape Joseph Henry for the main party. He returned on the 5th of October, after an absence of thirteen days. From the summit of a mountain about 2000 feet high, in latitude 82° 48′ N., he could trace the coast-line for a distance of sixty miles to the northwestward to latitude 83° 7′ N. Markham returned on the 14th, having succeeded in establishing his depot in latitude 82° 44′ N., and in sighting land nearly two miles further north. He had thereby surpassed the latitude reached by Parry forty-eight years ago, the highest latitude theretofore attained. Another party, sent out under Lieutenant Rawson on the 2d, to communicate with the Discovery, returned after an absence of ten days, without having accomplished its object. The ice was simply impassable.

On the 11th of October the sun had departed, and by the 26th the ship was completely housed in. On shore, the magnetic and other observatories were erected, and soon afterwards the officers in charge of the different scientific departments were hard at work. A school for the benefit of the crew was established; there were weekly theatricals, and the commander and his officers delivered weekly lectures on various topics that might be of interest or use to the men.

When the year 1875 drew to a close, diligent preparations were made for the sledging campaign to take place during the forthcoming spring. Contrary to the experience of the Polaris, the ice in the channel became stationary towards the middle of November; the last pools of open water seen off Cape Rawson disappeared towards the 20th, and no movement in the ice occurred during the winter. Merely a few tidal cracks outside the grounded floe-bergs could be noticed, and their width seldom exceeded a couple of feet, and this only at the time of spring tides.

The last bird seen, before darkness set in, was a snowy owl; this was on the 2d of October. Animal life was scarce, "a few eider ducks, a family party of longtailed ducks, a few turnstones, a single dovekey and a hare,"* were the only vertebrates seen near

* Feilden, *Notes from an Arctic Journal*, p. 44.

Floeberg Beach in 1875, if we except some specimens of charr, a small land-locked salmon. During the sledge-journeys made in the course of autumn, Markham came across four ptarmigan; a snow bunting was noticed in latitude 82° 35′ N., on the 14th of September, and the tracks of foxes, lemmings, and ermines were discovered, but not the animals themselves. In latitude 82° 33′ N., Feilden found the skeleton of a musk-ox.

On March 1 the sun returned after an absence of one hundred and forty-two days. Captain Nares, desirous of communicating with the Discovery, after the futile attempt made during the previous autumn, dispatched on the 12th Mr. Le Clere Egerton in charge of a dog-sledge. He was accompanied by Lieutenant Rawson, the officer of the Discovery who had left his vessel when the two ships parted company; the third member of the travelling party was Christian Petersen, the interpreter, who in the same capacity had shared the fortunes of Kane. On the second day out Petersen was taken sick. The party pitched tent, and while busy in preparing supper and attending the dogs, the two officers sent Petersen inside to shift his foot-gear and to get into his sleeping-bag. He neglected, however, to change his stockings, and had his feet severely frost-bitten, and his face and hands had suffered likewise. As it was impossible to keep him warm, they made a burrow in a snow-bank, and, carrying him thither, they tried to warm him by the heat of their own bodies. The condition of the patient became so critical that he had to be taken back to the vessel. Subsequently, both of his feet were amputated, and about two months later he succumbed to his sufferings. Egerton and Rawson, who had also been severely frost-bitten, renewed their attempt on the 20th of March, accompanied by two seamen; fully six days were, however, occupied in accomplishing the short distance that lay between the two vessels.

On April 3, fifty-three officers and men—all in the most perfect health—left Floeberg Beach with seven sledges. Markham, seconded by Lieutenant Parr, with two boats equipped for an absence of seventy days, was to force his way to the northward on the ice, to reach as high a latitude as possible. They were accompanied by three sledge-crews, who were to follow them as long as the state of their provisions would permit. Lieutenant Aldrich, assisted by a crew under Lieutenant Gifford, had orders to explore the shores of Grant Land towards the north and west.

On the 10th of April, Rawson and Egerton, who had returned from their trip to the Discovery the day after the seven sledges had left, started with a light sledge to mark a convenient road across Robeson Channel for the sledges of the Discovery, which were to explore the north coast of Greenland under Lieutenant Beaumont. Accompanied by Rawson, who had meanwhile picked a road, and by Dr. Coppinger, Beaumont left on the 20th of April. Three days later, Captain Stephenson arrived at Floeberg Beach from Discovery Harbor, and the two commanders consulted as to further steps to be taken. The crew of the Discovery had been well during the whole winter, and the temperature experienced had been almost as low as that registered by the Alert. Early in March the minimum temperature at Discovery Bay was 70.5°, and that at Floeberg Beach even 73.7° below zero. "The Alert's minimum temperature for twenty-four hours," according to Captain Nares, "was 70.31° below zero, the Discovery's minimum temperature for twenty-four hours was 67.0° below zero. The Discovery experienced a mean temperature for seven consecutive days of 58.17° ditto. The Alert experienced a mean temperature for thirteen days of 58.9° ditto; and for five days and nine hours of 66.29°. During February, mercury remained frozen for fifteen consecutive days; a southwesterly gale, lasting four days, then brought warmer weather; immediately the wind fell, cold weather returned, and the mercury remained frozen for a further period of fifteen days."*

Until the latter part of May, sledge-parties were constantly coming and going to keep up communications and to establish depots of provisions. Lieutenant Archer had explored Lady Franklin Bay, and found it to be a large fjord of some sixty miles in length, with valleys filled by glaciers; while Lieutenant Fulford and Dr. Coppinger had been examining Petermann Fjord.

On the morning of June 3, Lieutenant Parr arrived at Floeberg Beach with the distressing intelligence that Markham's party was suffering from scurvy. They had reached latitude 83° 20′ 26″ N., the highest latitude ever attained; they had struggled against natural obstacles unparalleled in the history of Arctic exploration, and had returned to Cape Joseph Henry. Captain Nares at once organized a relief-party headed by himself, which left towards midnight. Although Lieutenant May and Dr. Moss, in company with a seaman, made a forced march, they were too late to save the life of George Porter, Gunner, R. M. A., who had expired a few hours previous to their arrival.

* *Nature*, 1876, p. 35.

When the broken-down party arrived at the ship, early in the morning of the 14th, only five of the seventeen original members of the crew were able to drag the sledges alongside; the rest had to be carried. Markham had been absent for 72 days; his outward track extended to a distance of 319 miles, and his track home, to 281 miles, making a total of 600 miles (statute). A sounding taken at the northernmost point reached gave 72 fathoms with clay bottom; the temperature at the bottom was 28.8°, and that of the surface of the sea was only 0.3° less, while the temperature of the air was only 8° Fahrenheit. He had reached his highest latitude on the 12th of May, in longitude 63° 5′ W., as measured on his track-chart. The road had been difficult beyond description; a great deal of their way had to be forced by means of the pickaxe and shovel. The surfaces of the fields "were thickly studded with rounded, blue-topped ice-humps of a mean height above the general level of from 10 to 20 feet, lying sometimes in ranges, but more frequently separated at a distance from 100 to 200 yards apart; the depressions between being filled with snow deeply scored into ridges by the wind, the whole composition being well comparable to a suddenly frozen sea. Separating these floes, as it were by a broadened-out hedge, lay a vast collection of *débris* of the previous summers; broken-up pack-ice, which had been refrozen during the winter into one chaotic, rugged mass of angular blocks, of various heights up to 40 and 50 feet, and every possible shape, leaving little if any choice of a road over, through, or round about them." *

Similar conditions of the ice were noticed by the eastern and western divisions, commanded respectively by Lieutenants Beaumont and Aldrich. The former explored the north coast of Greenland to latitude 82° 18′ N., longitude 50° 40′ W.; the northeasternmost point sighted by him is probably situated in latitude 82° 54′ N., longitude 48° 33′ W. His party was also attacked by scurvy, and he had to deplore the loss of two men. After an absence of 120 days they arrived at Discovery Harbor on the 14th of August, and after an absence of 84 days Aldrich reached his ship on the 25th of June. The whole party suffered from scurvy; only the commander and two men were able to walk to the side of the vessel. He had traced the northern shore of Grinnell Land to about longitude 87° W., and had surveyed not less than two hundred and twenty miles of new coast-line.

The breaking out of the scurvy, and the insurmountable obstacles

* *Nature*, 1876, p. 40.

encountered by Markham during his journey over the pack, having fully demonstrated the futility of renewing the effort in the following year, Captain Nares announced his intention to abandon all further exploration in a northerly direction, and to proceed southward as soon as the ice should open. But to liberate the Alert was not an easy matter. A large number of torpedoes containing from 1 to 50 pounds of powder were used to clear a passage in order to effect an escape; the attempt proved successful on the morning of the 31st of July. A fresh southwesterly wind had blown the ice off-shore and cleared a channel to the southward. Soon afterwards, Cape Joseph Henry was lost to sight, but at Cape Union very heavy floes interfered with the progress of the vessel and detained her until the next day. The passage of Robeson Channel was extremely perilous; it was only by a combination of consummate skill, audacity, and good luck that it was finally effected. On the third day of August, the Alert was hemmed in by ice and was nearly pushed ashore at the same place where, on the 29th of the same month of the preceding year, her damaged rudder was stripped; here she was detained for eight days. When liberated, on the 11th, she gained Discovery Harbor in the course of the evening, and the two ships' companies were once more together. But Lieutenant Beaumont and his party were at Polaris Bay, and Captain Nares therefore decided to force the Alert across the channel in order to take the travellers on board. About noon of the 14th, Beaumont's party was discerned on the moving pack off Discovery Harbor, and early the next morning every surviving member of the division was on board. The two vessels were delayed until the 20th, when they pushed their way through the formidable floes and rounded Cape Lieber; but on nearing Cape Lawrence the ice became so close that they had to be secured to some of the floe-bergs grounded in the vicinity, and could not proceed until the 22d. Reaching Cape Collinson, the two vessels fouled for a few moments, but the whole damage done was the loss of a davit; the boat itself was saved. The first real icebergs met with in proceeding south were found in Rawlings Bay. After having been driven back twice to Maury Bay, the Alert and her consort successfully rounded Cape Frazer on the 24th, and on the 27th reached Dobbin Bay, where they were detained till the 3d of September.

Meanwhile, Sir Allen Young, who had left England on the Pandora, had reached the mouth of Smith Sound, wishing to land dispatches and letters at the depot near Cape Isabella. On the 3d of

August he was at Littleton Island. Twelve days later, he attained his highest latitude, viz., 78.45° N., in longitude 73° W., and found the sound filled with solid pack, stretching from shore to shore. He crossed and recrossed the sound looking out for any boat-party that might have been dispatched by the English exploring vessels; all this time he had to keep his ship constantly in motion to prevent her from being beset. During the first week of August, the winds were invariably blowing from the northward, and large unbroken floes came down the sound. One with six icebergs imbedded in it was of so great extent that it seemed to fill the strait from shore to shore. The outer or eastern edge of the pack always presented one unbroken curve from the direction of Cape Dunsterville, in the southwest, round to Cairn Point or Littleton Island, leaving a land water in Hartstene Bay. On the 27th, the Pandora was driven out of Smith Sound by a raging gale, while the two discovery ships had just reached Dobbin Bay, where they were detained until the 3d of September. The temperature had fallen to 19°; the young ice formed rapidly, and was so thick and tough that it was difficult to pass through it in a boat. On the 9th, Cape Isabella was rounded, and Markham landed to look for the mail, of which he obtained only a part, as he omitted to examine the cairn on the summit of the cape. The two vessels, now fairly clear of Smith Sound, worked slowly to the southward in the teeth of a persistent head-wind, and entered the harbor of Godhaven, on Disco Island, on the 25th of September. On the 2d of the following month they were both anchored at Portsmouth.

The results obtained by this expedition are of high value, both with regard to physics, geography, and natural history. Captain Feilden and the other naturalists of the party made extensive zoölogical, botanical, and geological collections; the last are of special interest, as they furnish the proof that Grinnell Land had a flora during the Miocene period similar to that of Spitsbergen, so ably described by Heer. Twenty-six species of plants were discovered in a seam of Miocene coal of great extent and thickness, exposed in a valley about two miles north of Discovery Harbor. The coal itself is pronounced to be equal to the best Welsh coal for steaming purposes; it has 61 per cent. of coherent coke; it cakes when heated, and leaves only 6 per cent. of ash.

The different expeditions hitherto considered furnish us with the material for a geographical sketch of the region in question; but for

brevity I shall limit myself to giving a short account of the condition of the ice and of the general character of the currents.

The character of the land bordering Smith Sound and its northern extension, is eminently that of a high-mountain region. By far the greater part of the Greenland coast may be termed a high plateau, rising to an altitude of probably not more than 7000 feet, as far as can be judged, from the present extent of our knowledge; but Ellesmere Land and Grinnell Land exhibit steep and lofty peaks, which are mostly isolated, from 2000 to 3000 feet high. Only two actual ranges of mountains have hitherto been noticed; one, the Victoria and Albert Mountains, the other, the United States Range, the highest peak of which, Mount Grant, is probably not over 3000 feet high. They both follow the general trend of the coast at a distance of some forty or fifty miles. Besides this striking difference, which would be noticed even by the most superficial observer, we see, furthermore, that Greenland, which has probably its highest elevations on its east coast, is covered by an ice-cap, while the coast opposite shows comparatively few glaciers. Before the return of the English expedition, it was not known that primary glaciers existed on Grinnell Land, at least not north of Hayes Sound.

Our present knowledge as to the depth of Smith Sound and its extension towards the north and south is still limited, but we are probably not much mistaken in assuming that the average depth of the sound is not less than 250 fathoms. By means of the cotidal hours of nine stations, Mr. Schott, according to Airy's formula, computed the average depth of Davis Strait to be 418 fathoms; that of Baffin Bay he finds to be 349 fathoms, and that of Smith Sound, between Van Rensselaer Harbor and Port Foulke, is 277 fathoms.* The average depth of Davis Strait and Baffin Bay is therefore about 383 fathoms.

The mean specific gravity of the water in Smith Sound, derived from 54 surface observations made by the Polaris, between August 12 and 28, 1872, between latitude 81° 35′ N. and latitude 79° 36′ N., is 1.02155, which is somewhat less than we might expect *a priori*. But we must take into consideration the time of the year at which these observations were made, and the fact that the vessel was always surrounded by ice. In only two instances was the temperature of the air below 32°, while during the rest of the period it was sufficiently warm to melt the ice; consequently the surface-water was rendered lighter than it would have been under other circumstances.

* Hayes' *Physical Observations*, p. 164.

According to Börgen, the mean specific gravity of the sea of East Greenland is 1.02411, north of the equatorial limit of the ice, while it is 1.02493 between the latter and the Arctic circle; and for Robeson Channel, during the winter of 1875–76, Sir George Nares found it to be 1.02245, which nearly agrees with our own value. The absolute maximum density experienced by the Polaris was measured at noon on the 20th of August, and amounted to 1.0288, which corresponds with the mean bottom density of the oceanic basins. Based on his own observations, Captain Nares comes to the conclusion that with the increase in temperature of the water, below thirty fathoms, the density also increases to above that of the polar water, which numerous observations made during the winter showed to be 1.02245. He concludes furthermore that the bottom water is derived from the Atlantic Ocean.* Eighteen observations made by the Polaris during the period above mentioned, in various depths, ranging from 6 to 203 fathoms, show a similar increase in density with the depth, although not at a regular rate. Whether these irregularities are due to undercurrents or to errors of observation will have to be decided by future investigations.

If we now examine the current system of the region in question, in its latest representation on Berghaus' Chart of the World, which embodies an admirable amount of details in the most instructive manner, we perceive that the west coast of Greenland is swept by a warm current. This warm current is represented as part of the Gulf Stream, consisting principally of two branches; the westernmost crosses the parallel of Cape Farewell between longitude 50° and 60° W., while the other sweeps the northwest coast of Iceland, whence it takes a westerly and southerly direction, and, passing round Cape Farewell, joins the branch first mentioned. Sweeping the west coast of Greenland, it can be traced to Cape York, whence it sets west towards the entrance of Jones Sound, from which we notice a cold current to issue, sweeping the shores of Baffin Land and Cumberland. In setting south, it is joined by another cold current issuing from Hudson Strait, and, designated as the Labrador current, it continues its way along the coast.

Besides these two main currents, we notice two subordinate cold ones; one runs across Davis Strait near the 70th parallel, while the other, a branch of the East Greenland ice-stream, runs along the southwest coast of Greenland, between the latter and the warm

*Nares, Vol. II., p. 158.

current before mentioned, nearly to the Arctic circle, one of its branches joining the Labrador current near latitude 60° N.

The materials on which the direction and velocity of these currents are based are derived from different sources; but evidently some portions were laid down by theory only. Before going any further it may be advisable to investigate briefly how much reliance can be placed in general on current observations made under ordinary circumstances in the Arctic seas. The vessels cruising in the region in question are either discovery-ships, whalers, or a few trading-vessels of the Danish Commercial Company. With few exceptions the discovery-ships are usually under strict orders, and are not allowed to deviate from their course or to make investigations; while the whalers, after they reach the ice, take hardly any astronomical observations, and never use their log-line. If a discovery-ship is not bound by orders, her commander may always have a certain plan which he can follow and to which he can make everything else subordinate; but unless this plan be the study of the physics of the sea, we can hardly expect any accurate observations. Cases like the latter are of rather rare occurrence, and there are but few on record. But even if a vessel starts purposely to make the observations in question, she will, in a great many instances, have to encounter physical obstacles that render the observations unreliable; often it will be quite impossible to make any observations.

The direction and velocity of currents are usually obtained by taking the difference between the position of the vessel as found by dead reckoning, and the position as determined by astronomical observations. A less common method is that of making actual experiments, which require much time and care. Owing to unavoidable errors of the dead reckoning, the former mode is far from accurate under ordinary circumstances, and it decreases in value if the vessel has to make her way through ice, when the log is rendered useless, and when she has to change her course so frequently that in some instances it is almost impossible to keep an accurate reckoning.

Those observations obtained when the vessel is beset in the ice and drifting are more valuable; but it is only under favorable circumstances that they give an accurate idea of the true velocity of the current. If there are many bergs scattered through the pack, the direction and velocity of the surface-current, as determined by two astronomical observations, may be considerably affected by undercurrents acting on the submerged parts of the icebergs; and the wind

will act on the exposed portion of the berg as on a sail, and thus in many instances solely determine both the rate and direction of the drift. The latter may also be greatly affected by the action of the tide, especially if the vessel is beset in a narrow channel.

To demonstrate the character of the currents in Kennedy Channel, Kane's Basin, and in Smith Sound, I shall herewith give an analysis of the drift of the Polaris. From midnight of August 14, with a light wind from SW., when the vessel got beset, till the evening of the 18th, between latitudes 82° 2′ and 79° 44′, the mean direction of the drift was almost SW., or more accurately, S. 42° W. Between the 14th and 16th it was either calm, or light winds were blowing from the NE., SW., and from S., most likely too light to affect the drift, the rate of which during the two days in question was five miles, decreasing to one mile during the following 48 hours, and rising to 14.4 between the 17th and 18th. This latter velocity is the greatest on record, and as fresh northerly breezes were experienced during the time, we may reasonably suppose that they accelerated the rate of the current, the more so as its direction remained the same as during the three preceding days. Most likely the increased velocity is also due to the action of the spring-tide, the moon being full at 8h. 53.2 m., on the 18th; and as a rule the set of the flood was found to be stronger than that of the ebb, the former being southerly. During the afternoon of the 18th a prime vertical observation was obtained, so that the position of the vessel could be fixed as accurately as the low altitude of the sun permitted. At 6 P. M. she found herself in latitude 79° 41′ N., longitude 70° 19′ W., and from this time during the following 48 hours the direction of the drift suddenly changed to about W. 17° N., the velocity decreasing to about 2.3 miles. Between noon of the 20th and noon of the 21st, the direction changed again, it being almost due SE., the velocity having increased but slightly, and all the wind recorded during this time being from the north. Another change of both direction and velocity took place between the 21st and 23d, the former becoming E. 9° S., and the latter having increased from 3 to 6.5 miles, while the resulting direction of the wind during this time was almost at right angles to the set of the current.

While up to this time the rate of the current was never less than one mile during 24 hours, we see that it decreased to almost one-half of this velocity during the period from August 23 to September 6, the wind being very light during the whole time, with the exception of two instances, when fresh breezes from SW. are recorded.

The whole difference of latitude made during this fortnight was only five miles, the direction of the set being very variable and apparently quite independent of the wind. This rather remarkable change finds its explanation in the meeting of the eastern and western Atlantic tidal waves, and Sir George Nares has found by observation what I had proved theoretically, viz., that the two waves meet near Cape Frazer.

Between September 6 and 8 the direction of the set was about W. 10° S., the rate increasing again to 2.5 miles and remaining the same until the 14th, although the resulting direction changed to almost SW., the wind being north during the greater portion of the time. From the latter day to October 2, the direction was nearer to that of the meridian than in any of the other instances, the velocity decreasing from 2.5 miles to 1.5, becoming as small as one mile between September 24 and October 2.

The vessel, continuing to drift towards the coast, followed its trend very closely from the 8th till the 13th, the velocity increasing to 85 miles, most likely accelerated by the wind, which was from the northeast. The last observation on record is a meridian altitude of the sun taken on the 12th, and placing the ship in latitude 78° 28′ N., about 6 miles off Cape Hatherton. Increasing her distance from the shore, as a glance at the map will show, she began to drift to the west side of the channel, taking a somewhat northerly direction, partly caused by a fresh breeze from northeast, which finally changed into a southwest gale. Towards evening she was carried north to the vicinity of Lifeboat Cove at the rate of at least three miles an hour; but most likely this speed was not only due to the influences of the wind, but also, and perhaps principally, to the flood current, it being the time of spring-tide.

In the same latitude, a little to the eastward of our position, Inglefield experienced a northerly set of 3 miles, which we do not hesitate to assign to the same cause, as a permanent current of such a velocity does not exist at this place. In the spring of 1873, when travelling from Polaris House to the Eskimo settlement, Sorfalik, where we remained a short time, we paid special attention to the motion of the ice, which, during the time of slack-water, was invariably towards the south. The same direction of the set, only at a greater rate, could be noticed when the tide was ebbing; when the tide was rising, the ice drifted in the opposite direction at a speed of about four miles an hour.

From the preceding observations, it becomes evident that the

resulting direction of the current is southerly, even between Port Foulke and Cairn Point, where Petermann supposed the existence of a branch of the Gulf Stream.

That there is no warm current north of Cairn Point was proved by numerous observations taken on board of the Polaris before she reached her second winter-quarters. But we may properly ask, what are the conditions south of that locality? If the eastern shores of Smith Sound are washed by a warm current, this current will necessarily have to enter the Sound from the southward. I must confess that I have no actual current-observations to offer here, but as the Gulf Stream is partly characterized by a high temperature it can be traced by the thermometer. During our retreat in the boats from Polaris House to Cape York, between June 3 and 21, I measured the temperature of the sea as frequently as was necessary; I found it either invariably at that of the freezing point of fresh water or even below 32° F. The existence of the Gulf Stream between Cape York and Polaris House is therefore out of the question. But might not a warm current enter Smith Sound to the westward of the track of the boats?

To this we can positively answer, no, for we found the temperature of the sea in no instance above 31.6° when crossing from Cape York to the coast of North Devon, during the first part of July. Had there been any traces of a warm current we should have found them beyond doubt, as we usually took observations every hour, or even as often as every half-hour, when the color of the water showed any changes.

According to these observations, the Gulf Stream does not extend north of latitude 75° 5′; but how far it reaches cannot yet be stated, as our own meteorological observations bearing upon this subject are lost, and the materials thus far published are hardly sufficient to settle this question definitely. In McClintock's *Meteorological Observations* we find the following remark made on the 7th of July, 1857, the Fox being in latitude 66° 6′ N., longitude 15° 1′ W.: "The temperature of the sea-surface varied from 56° to 61° during the day. At noon the following day the position, by observation, was 10′ to NE. of the dead reckoning. The yacht, therefore, was probably on the northern limits of the Gulf Stream." An examination of the same register shows, however, that afterwards higher temperatures were noted till the vessel had passed the parallel of Upernivik, when the water again became colder. Some manuscript observations, kindly furnished to me by Captain von Otter, of the Swedish Navy, seem

to indicate the same conditions; and until we shall have some more complete data, we shall hold the opinion that the Gulf Stream does not enter Melville Bay.

In order to solve the Gulf Stream question in a satisfactory manner, the observations on the temperature of the sea ought to be accompanied by determinations of the specific gravity of the water, because in many instances the high temperature alone is not sufficient to prove the existence of the Gulf Stream. We have shown that there is no warm current entering Smith Sound, and still we found that on several occasions the temperature of the water at Polaris Bay was astonishingly high. On the 2d of August, at 3 P. M., we noted a temperature of 51.9° along the shore, a little south of our anchorage and opposite a ravine named the Second Ravine, but at the same time the water was almost fresh.

We made similar observations along the Greenland coast between Disco Island and Upernivik, and in every instance we noticed that these warm spots were almost destitute of animal life, which was abundant where the percentage of salt was normal. How this high temperature is imparted to the water is easily perceived.

It is greatly to be regretted that the current observations of the expedition under Sir George Nares have not yet been published, for it is still hardly possible to make his observations agree with ours. At noon of July 26, 1875, the Alert, when about fifteen miles southwest of Wolstenholme Island, obtained a surface temperature of 40°, and when near the Cary Islands, on the same day, she found a stratum of water of a temperature of about 39°, extending to a depth of 12 fathoms.* When on their way home on the 16th of September, 1876, Sir George obtained a temperature of only 27°, almost at the same place where it had been 12° higher the year previous, while he found a belt of water of a temperature of 34°, almost fifty miles wide, half way across Baffin Bay on the parallel of Jones Sound.

According to these observations, it appears that the currents in the region in question are subject to great changes. If it were possible to trace a connection between the changes of these currents and the cool and warm summers in West Greenland, some other highly interesting problems might easily find their solution.

Let us now briefly consider the condition of the ice.

The ice met by the Polaris in Robeson Channel was of a different character from that which baffled the heroic efforts of the British

* Nares, *Voyage*, Vol. I., p. 44.

explorers. It is true that Hall, in October, 1871, noticed some ice in Newman Bay which he called "*century-old ice, that, commencing from one side of the bay, spreads over to the other*"; * but we met only in a few instances with those formations called floe-bergs by Sir George, and I cannot be easily convinced that the condition of the ice in Lincoln Sea is always such as it was found in 1875 and 1876. That ice of such immense thickness should form according to the regular freezing process is contrary to all physical law. The ice formed on the surface of the sea is subject to regelation similar to that of glacier ice. Where the pressure is strong, high hummocks will be produced, and the snow, under the influence of the wind, will be deposited and packed between the hummocks and form drifts, which are subject to the same changes as the névé of a glacier; and how heavy the pressure is in the region in question may easily be noticed if we examine the high walls of ice pressed up at various places along the shores of Smith Sound. In Melville Bay I noticed comparatively smooth floes, which projected some ten feet above the level of the sea, but their height was due only to the masses of ice that had been pressed under them. The floe-bergs evidently form in the same manner. Under the influence of the prevailing winds and the currents, the lighter ice necessarily escapes from Lincoln Sea, while the heavier masses will get aground, and may remain in that position for several years. The ice in the Polar Basin necessarily has a tendency to drift towards the equator, and there is no reason to assume that the ice-cover of the sea in close vicinity of the North Pole should be more dense and impenetrable than in lower latitudes. For, the higher the latitude, the longer the sun will be circumpolar, and therefore, although its altitude may be low, the sum of heat received by the surface of the sea or land will be greater. I do not wish to be misunderstood, as I do not believe in an "*Open Polar Sea*"; but neither, on the contrary, do I believe in a sea covered by impenetrable ice year after year.

The sounding obtained by Markham when he reached his northernmost position, and the hummocks discolored by mud noticed by the northern division, seem to indicate the presence of land to the northward of the highest latitude attained by this gallant explorer. If any land exists there, it will probably be an archipelago, separated by more or less narrow bodies of water, whose ice-cover may be stationary for several years in succession. If, then, an abnormal

* *Narrative*, p. 167.

season should occur like the one experienced by Sir George, as may be proved by the westerly winds, these channels will be cleared and the ice will drift to the southward.

I have repeatedly alluded to the character and motion of the ice as found by the English expedition in 1875 and '76. Between 1871 and '73 the conditions were different and the various channels were never entirely frozen over. If we take the prevailing direction and force of the wind into consideration, and if we remember that Robeson Channel and the others adjoining it are narrow, and, comparatively speaking, very deep, thus giving occasion to a swift tidal current, we can hardly expect anything else. During the winter and spring of 1871–72, the only stationary ice near our winter-quarters was found along the shore, extending in a narrow belt from a few miles north of Cape Lupton, along the shores of Polaris Bay, to the mouth of Petermann's Fjord, and growing very hummocky near Cape Lucie Marie.

South of Cape Morton, along the northwest coast of Petermann's Peninsula, it was found a little smoother in April, 1872, although intersected by lanes of water, while there was hardly an ice-foot along John Brown Coast; a travelling party trying to reach Cape Constitution was stopped by open water and had to return. As far as the observations made at Polaris Bay and Newman's Bay go, the ice in the channel was adrift during the greater portion of the time; it was stationary only on a few occasions during March, when the temperature was low and when there was not much wind.

Owing to the combined action of currents and winds, the ice forming in deep channels, flanked by steep shores, will always be found hummocky; and, indeed, in Robeson Channel and Hall's Basin it was of the worst description. It was rougher than that of Smith Straits, the bad condition of which prevents the natives living near Cape Alexander from crossing the strait, barely thirty miles wide, and from communicating with the Eskimos inhabiting the region of Ellesmere Land near Cape Isabella.

During the spring and summer of 1872, the sea in Hall's Basin and Robeson Channel was in such a condition that during the navigable season, the lanes of open water intersecting the ice were hardly wide enough to permit a boat to be launched, while they were too numerous and the ice too rough to encourage sledge-travelling.

In Hall's Basin the drift of the ice was in most cases southerly, accelerated by northeast winds and the flood-tide, which runs stronger than the ebb. The influence of the latter is less marked, and it was

only when the returning ebb was accompanied by southerly winds that the ice drifted with the same velocity in a northerly direction as in the opposite one. During the stay of the boat-party at Newman's Bay, the direction of the drift was also southerly, with the exception of a few occasions during the time of spring-tides, when a slow motion in the opposite direction could be noticed for a few hours at a time.

During the latter part of the summer of 1872 the condition of the ice was less favorable to navigation than during the preceding year; but between the 16th of August, when the vessel was beset, till the middle of September, lanes of open water of greater or less extent could be noticed almost daily along the coast of Grinnell Land. To reach them by the vessel was, however, impossible, owing to the absence of westerly winds, upon which the navigation of Smith Sound almost wholly depends.

When the boats left Polaris House, June 3, 1873, they coasted at a distance of from one to four miles from the shore in clear water, meeting floating hummocks only occasionally, although the pack was in sight nearly all the time to the west. Arriving at Cape Saumarez, the solid land-floe was met, stretching along the meridian of this cape as far south as Northumberland Island. To the northwest of this island and of Hakluyt Island, a considerable pack had accumulated, and the boats met more or less loose ice on their passage, most being encountered off Whale Sound, which, on the 12th of June, was still covered by the solid floe, extending from a short distance north of Cape Parry along the shore and across Booth Sound to Blackwood Point. For about eight miles south of this locality the coast was perfectly clear of ice; then the fast land floe was encountered, stretching to the northwesternmost extremity of Saunders Island, and in the direction of the meridian to the eastern portion of the north coast of Wolstenholme Island, while Dalrymple Rock was accessible. The floe appeared again at the southeast point of Wolstenholme, extending southeast to about longitude 72.5° W. As the boat's track from Wolstenholme Island to Cape York led always along the margin of the land-floe, which was smooth and very level, a glance at the map will show how far the latter extended to the seaward.

In one of the preceding chapters I have mentioned the occurrence of a seam of tertiary coal in Lady Franklin Bay, discovered by

the British Expedition under Sir George Nares. Shortly after the return of the English vessels a Lieutenant of the Army, then property and disbursing officer of the U. S. Signal Office, advocated a plan to reach the North Pole via Smith Sound, which was mainly based on the existence of the coal seam near Discovery Harbor.

This plan, termed the Howgate plan, was devoid of all sound originality. The valuable parts of it are based on the work of Hayes and Weyprecht; the rest, emanating from the brain of Lieutenant Henry W. Howgate, bears testimony that the originator of the "*Howgate Plan*" was not familiar with even the rudiments of Arctic exploration. This indigestible hash of reasonable and ridiculous views, after having been thoroughly mixed by Howgate, was seasoned by the daily press and made palatable to the public at large. Finally it was put into shape by a well-known penny-a-liner and presented in pamphlet form to the forty-fourth Congress.*

On page 6 of the pamphlet is written the following sentence: "*There prevails, indeed, even now, among the Esquimaux, traditions of lands far north of their own, inhabited by a people superior to themselves in knowledge and intelligence; lands where long-bearded men fatten the musk ox, and where churches and clocks are found.*" The author of the above does not hesitate to slander the most experienced Arctic explorers in various other paragraphs of the same publication. He points out their shortcomings and errors, and advises their successors how to avoid them, and what to do. He enumerates the causes of failure, and discusses after his own fashion the severity of seasons, the loss of time, and the hardships endured between the starting points and the regions proximate to the field of discovery; the lack of anti-scorbutics, lack of proper discipline, the failure to employ Eskimos, and the imperfect means of communication between the various field-parties. He proposes to send a party of fifty officers and men, or more, regularly mustered into the U. S. Army; an astronomer and two naturalists; one or two members of the regular force to be selected with reference to their ability in meteorological observations and telegraphy; skilful surgeons with supplies of medicines; a number of Eskimos, and an ample supply of Eskimo dogs. Provisions are to be stored for three years, though an annual visit from the United States is suggested as desirable. A strong portable building is to be carried to the station; two miles of wire to establish

* Polar Colonization and Exploration, by H. W. Howgate.

telegraphic communication with desirable points; and, of course, full sets of instruments and equipage, to make the parties efficient in all pertaining to the work of the expedition.

The plan of operations suggested is a sledge journey between the base of operations and the Pole, arranged in eight stages, fifty miles apart. It is proposed to start eight sledges laden with provisions; a portion of the provisions is to be cached at the first station and the sledge sent back; the second sledge is to leave its surplus at the second station and then return, and, following out this plan, only one sledge with ten or more men will continue throughout the journey, and, having made the necessary observations, will return. The caches are to be visited on the homeward route and provisions taken as needed.

International coöperation is referred to in the pamphlet, but not discussed, save with reference to projected independent voyages by other nations. The projector asks Congress for the sum of $50,000 —an inconsiderable amount indeed, if compared with the cost of previous expeditions fitted out. On the 8th of January, 1877, Mr. Hunter, of the House of Representatives, actually introduced a bill to carry out Howgate's plan. He asked for the sum above named, and for a vessel to convey the party; but the bill, although favorably reported from the Committee on Naval Affairs of the House of Representatives, failed to pass.

Howgate, bound to keep himself before the public, now freely applied to the public for support, and, according to his own statement, received a sufficient sum of money* to fit out a small preliminary expedition to Cumberland Gulf to collect the necessary supplies for the final voyage.

The expedition left in the schooner Florence, which had been purchased and fitted out for the purpose, and returned after a year's absence; but Congress had not felt inclined to favor the enterprise and give it the support asked for by its advocate. Congress could hardly have acted otherwise, for, as soon as Howgate had made his plan public, some of those familiar with Smith Sound, with its ice, and the chances of its navigability, pointed out the folly of the scheme.

At the risk of being indiscreet, I shall here quote a passage from a letter of Capt. Albert H. Markham, R. N., whose experience in the navigation of Smith Sound is second to none. On the 24th of February, 1877, Markham wrote to me from London, regarding the so-called Howgate plan: "It all reads and sounds very well, and per-

*Cruise of the Florence, p. 5.

haps may delude the inexperienced public; but speaking as an arctic man myself, I must confess that the scheme is utterly impracticable, and one that could only emanate from the brain of a conceited man desirous of notoriety, who has compiled his pamphlet from the works of others and brings it out as his own originality."

After Howgate had discovered that the opponents of his plan in Congress could not easily be snared, he changed his tactics. He now tried another bait. Purchasing for a mere song a small Clyde steamer in Scotland, which was brought to this country early in 1880, he caused another one of his friends to introduce another bill on his behalf in which the following passage is of some interest: " . . . . . Provided, That the President of the United States is authorized to accept from H. W. Howgate, and fit out for the purpose of this expedition, the steamship Gulnare, which vessel shall be returned to its owner, when the object of the expedition shall have been accomplished, or when, in the opinion of the President, its services are no longer required."*

This was by no means a bad speculation on the part of Mr. Howgate, as the cost of fitting the vessel for Arctic navigation proved afterwards to be over four times the amount he paid for her. While the bill was being discussed in the House of Representatives an opportune article appeared in the New York *Herald*, of which every member found a copy on his desk when taking his seat. Previous to that a number of other impartial but biting articles had been published. When Howgate most certainly expected to see his bill pass, it was miserably defeated. Those who opposed it showed much good judgment in so doing, and whether they opposed it on general principles or on some special ground, is not of much consequence in this instance, for Lady Franklin Bay should have been the last place chosen as a permanent or temporary station.

In the first instance it could never have been made self-supporting, as Howgate expected; for, the game inhabiting the land in those latitudes, even if comparatively plentiful at first, would very soon be exterminated; and the spoils of the sea are so scant that the Polaris and the two vessels under Sir George Nares did not secure over twenty seals in the course of two years. The birds too are not found in such great numbers as farther south; the northernmost rookery of the little auk is in Foulke Fjord, and the sportsmen of the Alert while in winter-quarters obtained only one hundred and nineteen birds, and

* Compare "Appendix," pp. 3 and 4.

those of the Discovery not more than eighty-four. If any geographical discoveries were to be made, the exploring parties would necessarily have to go first over the ground explored by the eastern and western English division under Beaumont and Aldrich, before entering a new field; and they would have to traverse the hummocky ice of Lincoln Sea to get beyond Markham's farthest point, reached in 1876. As another reason why Lady Franklin Bay should not have been chosen as a station, it is sufficient to state that in Smith Sound and its northern extension, the meteorological stations are more numerous than anywhere else in high northern latitudes. At that time there were six: *Floeberg Beach*, *Discovery Harbor and Polaris Bay*, *Rensselaer Harbor*, *Polaris House*, *and Port Foulke*, and all these within less than four degrees of latitude. If Howgate had proposed to provide his party with a steamer to winter at the station, and not *to be returned to her owner*, *after having landed the expedition*, there would have been at least *one* redeeming feature in his scheme; for then the colonists might have seized the first favorable opportunity to explore the region to the northward of Lady Franklin Bay.

Notwithstanding the deathblow the bill had received both in the Senate and in the House, Howgate still bore his banner with the utmost temerity. One morning the leading newspapers of the country, through the Associated Press, published the surprising statement that "Captain" H. W. Howgate would fit out the Gulnare at his own expense. And a surprise it was; especially to those who had been familiar with the straitened circumstances of Howgate, who, at one time a poor carpenter, had risen from the ranks to the grade of a first lieutenant, with pay not over-abundant. In what manner the money to fit out the expedition had been obtained was unknown at the time, but not many months elapsed ere the mystery was revealed.

The Gulnare had anchored in the Potomac opposite one of the wharves, and from my working room in one of the towers of the Smithsonian Institute I had her constantly in sight. Howgate had given strict orders not to allow any one to visit the vessel, but, in company with Mr. Chester, who had been first mate of the Polaris, and who had finally helped to fit her out, I went on board. Clad in the humble garb of workmen we succeeded in allaying the suspicion of the guard, and thoroughly examined the vessel, pretending to be mechanics sent by Howgate. She was taken to Alexandria to be rebuilt. After her boilers had several times been condemned by the inspecting

officers, she finally left with flying colors, but under different auspices than Howgate had expected; for the Secretary of the Navy refused to furnish the necessary complement. In a disabled condition she returned in the fall of the same year, leaving the surgeon and one of the scientific members at Disco.

Meanwhile the International Arctic Congress had for the first time been in session, at Hamburg. During the meeting of the meteorologists at Rome,* General Albert J. Meyer, then Chief Signal Officer of the Army, had made the acquaintance of Lieutenant Charles Weyprecht of the Austrian Navy, the originator of the plan of polar stations. The Austrian explorer subsequently addressed to him a letter, dated Trieste, May 20th, 1879, requesting him to induce the U. S. Government to take an active part in the proposed investigations of the Polar Regions. This letter was answered by the Chief Signal Officer on September 8.† It contains the statement that the Department would be willing to coöperate with "any State or States or responsible parties in extending in this manner the system of simultaneous observations, and will favorably consider the subject of a station at Point Barrow."

There is no evidence that the Chief Signal Officer of the Army up to that time expected to include Lady Franklin Bay in the cordon of meteorological stations; but the influence exerted by Howgate seems to have been so powerful that he finally concluded to do so. From a historical point of view it will be interesting to the student of Arctic exploration to compare the letter of General Meyer‡ to the Secretary of War, with the House Report No. 89,§ and the substitute for the House Report No. 1823.||

I have perhaps dwelt longer upon the Howgate plan than I should have been justified in doing under ordinary circumstances; but I had to discuss it at some length, for it fatally influenced further Arctic exploration, as we shall presently see. That this plan would lead to disaster was pointed out by myself and others at an early date; but the judgment of the Chief Signal Officer in Arctic matters was considered supreme, and upon him rests the responsibility of its failure. Several names connected with the Signal Office will not easily be forgotten in Arctic history.

*Appendix, p. 137.

† *Loc. cit.*, p. 138.

‡ P. 138 *et seq.*

§ *Loc. cit.*, p. 142.

|| *Loc. cit.*, p. 149–50.

Finally it was decided to establish a station at Lady Franklin Bay, besides the one at Point Barrow, and, by Special Order No. 57, First Lieutenant A. W. Greely, Fifth Cavalry, Acting Signal Officer, was assigned to the command of the expeditionary force then organizing under provisions of the acts of Congress, approved May 1st, 1880.*

The first paragraph of Greely's general instructions† reads to the effect that "the *permanent* station will be established at the most suitable point north of the eighty-first parallel and contiguous to the coal seam discovered near Lady Franklin Bay by the English Expedition of 1875."

I have quoted this paragraph in full to show how thoroughly the present Chief Signal Officer had imbibed the idea of Howgate.

The steamer, to be chartered in Newfoundland, was to touch at Disco or Upernivik in order to obtain Eskimo hunters, dogs, clothing, and various other necessaries, and was then to proceed northward, making only such stops as the condition of the ice would necessitate or such as would be essential in determining the exact location and condition of the stores cached on the east coast of Grinnell Land by the English expedition of 1875. Greely was furthermore directed to supplement the English depots by small caches from the steamer's stores and provisions, in case he should be delayed by the condition of the ice, and to leave three brief notices of his visit; one to be deposited in the cairn built or found standing, one to be placed on the north side of it, and one to be buried twenty feet north (magnetic) of the cairn. After arriving at the permanent station the steamer was to discharge her cargo with the utmost dispatch, and, having allowed the remaining party to make a careful examination of the seam of coal, she was to return to St. Johns, N. F.

The first duty of the party would then consist in erecting the dwelling-house and the observatories, and in making an attempt to reach the "high land near Cape Joseph Henry" by sledges. The sledge-parties were to work in the interest of exploration and discovery, and to make accurate surveys of the unknown parts of the country.

Regular meteorological and other observations were to be maintained uninterruptedly, in accordance with instructions issued to

* *Loc. cit.*, p. 141.

† Instructions No. 72, dated Washington, D. C., June 17, 1881. "Appendix."

Signal Service observers and with those published by the Board of the International Arctic Conference. It was contemplated to send a vessel in 1882 and 1883 to visit the station, and to carry supplies. In case she should be unable to reach Lady Franklin Bay during the first year, she was to cache a portion of her supplies and all of her letters and dispatches at her most northerly point on the east coast of Grinnell Land, and to establish a small depot of provisions at Littleton Island. Notices of such depots and their localities were to be left at Cape Hawks, Cape Sabine, and at Cape Isabella, or at any one of these points, if all should not be accessible.

The paragraph of the general instructions relating to the movements of the vessel, to be eventually despatched in 1883, is of vital importance, as we shall see hereafter, and I shall therefore quote it in full. It reads as follows:

" . . . . . the vessel sent in 1883 will remain in Smith Sound until there is danger of its closing by ice, and, on leaving, will land all her supplies and a party at Littleton Island, which party will be prepared for a winter's stay, and will be instructed to send sledge-parties up the *east side of Grinnell Land* to meet this party. If not visited in 1882, Lieutenant Greely will abandon his station not later than September 1, 1883, and will retreat southward by boat, following closely the *east coast of Grinnell Land*, until the relieving vessel is met or Littleton Island is reached."*

For the purpose of conveying the expedition, which consisted of three lieutenants, three sergeants, four corporals, and nine privates, to Lady Franklin Bay, a sealing steamer was chartered at St. Johns, Newfoundland. This was the Proteus, built at Dundee, in Scotland, in 1874. She was barkentine-rigged, and had a registered tonnage of 467 tons and a gross tonnage of 619 tons. She had been expressly built for ice-navigation; she was provided with a sheathing of iron-wood from above the water-line to below the turn of the bilge; her prow was armed with iron, and she averaged 8½ knots.† Commanded by Captain Pike, an ice-master of great experience, she left St. Johns at noon, July 7, and reached Godhaven nine days later. The only ice seen south of Cape Farewell were a few bergs off Funk Island; the pack was encountered at 10.30 P. M., July 12, lat. 61° 30′ N., long. 53° 30′ W., and was left behind at 3 o'clock

***Loc. cit.*, p. 7.

†For description of vessel compare "Appendix," Inclosure i., pp. 22, 23.

the next morning. A second mass of pack was met at 2.30 P. M. the same day and passed through in an hour. Dr. Octave Pavy, who had been left by the Gulnare at Disco, joined the expedition as acting assistant surgeon on the 20th, and after twelve dogs, to which nine more were subsequently added, and other necessaries had been taken on board, the Proteus weighed anchor and left the colony on the 21st for Rittenbenk, where Henry Clay, who had wintered in Greenland with Dr. Pavy, also joined the ship.

On July 24th the Proteus was at anchor at Upernivik. Lieutenant Lockwood proceeded to Pröven in the steam launch and secured the services of two natives; he also obtained ten dogs, five of which died shortly afterwards. The weather reports were extremely favorable; the winter had been uncommonly mild, and according to the statement of Mr. Krarup Smith, the Inspector of North Greenland, "Upernivik had never been so green in fourteen years."* On the afternoon of July 29 the anchorage of Upernivik was left, and at 7 P. M., having run through the south passage, the vessel was distant three miles from this settlement. Running northward for a few hours, the middle passage was taken, and at 7 A. M., July 31, the engines were stopped, as the dead reckoning placed the vessel only six miles north of Cape York, and the land was hidden by dense fog. When it cleared, an hour later, the land proved to be about five miles distant. The transit of Melville Bay had been made without any difficulty and in the remarkably short time of thirty-six hours. The only pack seen was sighted in latitude 75° 08′ N., longitude 63° 40′ W., but it lay to the westward of the ship's track, and it was not possible to discern from the masthead whether it was solid or loose. In the course of the afternoon two parties were landed on the southeast island of the Carey group. One party, under Dr. Pavy, found the cairn left by Sir Allen Young, while the Commander, in company with Lieutenant Lockwood, examined the whaleboat and depot of provisions left by Sir George Nares, which they found in good condition.

Shortly after midday on the 2d of August, Littleton Island was reached. An exhaustive search of seven hours revealed the English mail, contained in four boxes and three kegs. It was taken on board to be forwarded to England. A small cairn found close by did not contain any records. On the southwest side of the island, facing Cape Alexander, about 6½ tons of coal were landed. A party visiting the old winter quarters of the Polaris, to communicate with the natives,

* Appendix, p. 27.

found that they had left. The party brought back a number of relics, among them the transit instrument, which was picked up near our old cairn. This cairn, like the cache containing our records and instruments, had been overlooked by Captain Greer and his party when in search of us.

Some repairs to the wheel of the vessel caused a delay of several hours, but nevertheless Littleton Island was left at 10.45 P. M. There was no ice visible; the weather was fair and the Proteus made a direct run for Cape Hawks, without examining the depot of 240 rations left by Sir George Nares at Cape Sabine. The next landings made were at Washington Irving Island and Cape Hawks. The stores and provisions left by the English expedition at the latter place were found in comparatively good condition, except the bread, which was somewhat mouldy. Here were taken on board the jolly-boat belonging to the depot, a keg of Jamaica rum, and also some samples of provisions. The remaining stores were more perfectly secured to resist the weather. The vessel made a new start at 11.10 A. M., to pick up a party that had been left on Washington Irving Island, and then proceeded northward, passing Cape Louis Napoleon at 1.10 P. M., and Cape Frazer about two hours later. Through the openings of the fog, which commenced setting in, Washington Land was first sighted at about four o'clock. Dense fog prevented the commander of the party from visiting the English depot at Cape Collinson, where Sir George Nares had left 240 rations, and he was finally compelled to stop. When it cleared again, Franklin Sound was sighted and passed shortly before noon. At two o'clock in the afternoon the Proteus stopped at the northeast point of Carl Ritter Bay, where a depot of 225 bread and meat rations was established, on the first terrace of the shelving beach, north of a characteristic small creek. When off Cape Lieber the vessel encountered the first pack to interfere with her progress; it extended across the sound from Cape Baird to Offley Island, and consisted of heavy ice, ranging from 20 to 50 feet in thickness. The Proteus was moored to a floe; meanwhile a party went on shore to examine the ice, and Lieutenant Lockwood erected a cairn on the highest point near Cape Lieber. "*No other cairn could be seen on it or from it nor on other peaks visited by Dr. Pavy and myself*";* this is a further proof that Dr. Hayes did not reach the latitude he claims to have attained, for a cairn or its traces are

* Appendix, p. 28.

not easily obliterated. Its site would even be detected if it had been partly blown down or entirely demolished.

On August 6th the motion of the pack forced the vessel to make various changes of her mooring place. The next day she was driven out of Lady Franklin Bay, and on the 8th she slowly drifted south. About twenty-five miles of ice in huge fields passed southward of her during those two days. On the evening of the 8th the steady north wind packed the ice, which formed a close barrier, stretching from Carl Ritter Bay across to Hans Island. A nip appeared unavoidable. Preparations to unship propeller and rudder were made with all possible dispatch. During the night the conditions improved slightly, but during the 9th and 10th of August the Proteus drifted to within five miles of Hans Island. She had lost about forty-five miles of latitude. A southwest gale, accompanied by snow, finally drove the pack to the northward. This was on the 10th. When it cleared the next morning, the open water along the coast of Grinnell Land extended as far to the north as the eye could reach from the crow's-nest. The Proteus now made a new start and was fortunate enough to cross Lady Franklin Bay a little before three o'clock in the afternoon, when she entered Discovery Harbor by a narrow lane of water, left between the pack, which was jammed against the shore.

The Proteus had evidently made a most remarkable passage, having actually reached her destination in *six days and two hours, including the various stoppages*. While Lieutenant Lockwood examined Watercourse Bay and the coal seam, the Commander visited the winter-quarters of the Discovery. The former returned early in the morning of the 13th, reporting the place suitable for camp. The coal was easily accessible and could be sledged to Discovery Harbor or Watercourse Bay without great difficulty after the ice had formed. It was only with reluctance that Lieutenant Greely decided to settle at the winter-quarters of the Discovery, for the vessel, while being unladen, was exposed to all winds from NE. to SSW. Passing some two miles of heavy ice, the Proteus finally anchored towards three o'clock in the afternoon of the 12th about one hundred yards off the cairn left by the Discovery. Half an hour later the force was "divided into two gangs to work day and night by four reliefs until the cargo was discharged." The coal, of which the expedition had about 140 tons, was landed, and the work on the house was proceeded with, although but three or four men could be spared. Fourteen musk oxen had been killed, furnishing a quantity of meat sufficient

for seven months, if issued three times a week. In grateful remembrance of the lively interest that the Senator from Michigan had taken in having the station established, Lieutenant Greely named his camp Fort Conger.

On the 25th (?) of August the Proteus left for St. Johns, having two men of Greely's original force on board. As far as I have been able to ascertain, there are no documents in existence containing information as to the condition of the ice in Smith Sound during the homeward voyage. But the trip was evidently of short duration, for a telegram received at the office of the Chief Signal Officer at 9.43 A. M. on September 12, announced the safe arrival of the vessel at St. Johns.*

The last despatches sent by Greely entitle us to the highest expectations, for he had conducted the expedition under his charge with uncommon energy, great prudence, and good judgment. In a letter to the Chief Signal Officer he recommends that in connection with the vessel to visit the station in 1882, a captain of the merchant service should be sent who had had experience as a whaler and ice-master. He further requests that five enlisted men of the army be sent to replace invalids or men otherwise unfit for work. In case the vessel should be unable to reach Camp Conger she should be directed to leave a boat and a depot of provisions at some prominent point on the east coast of Grinnell Land, in the highest latitude attained. Another depot should be left at the western point of Littleton Island, and a second boat at Cape Prescott, or as near to this place as possible. After making the depot at Littleton Island, the vessel should, if possible, leave a record of its proceedings at Cape Sabine.

In case the party should not be able to visit Camp Conger in 1882, Lieutenant Greely proposes that the following year a capable, energetic officer should be sent with ten men, eight of whom should have had experience at sea, provided with three whaleboats and ample provisions for forty persons for fifteen months. In case the vessel, *which was not to leave Smith Sound before September 15th*, should be obliged to turn southward, she should establish two depots like those above mentioned; one between Cape Sabine and Bache Island, the other at a point intermediate between two depots already established, and marked by substantial scantling, well secured and braced, to the top of which pieces of canvas should be nailed, so that

*Appendix, p. 33. 3012 Misc., '81.

the depots could be easily discovered. "*The party should then proceed to establish a winter station at Polaris winter-quarters, Life-boat Cove, where their main duty would be to keep their telescopes on Cape Sabine and the land to the northward. They should have lumber enough for house and observatory, fifty tons of coal, and complete meteorological and magnetic outfit. Being furnished with dogs, sledges, and a native driver, a party of at least six* (6) *men should proceed, when practicable, to Cape Sabine, whence a sledge party northward, of two best fitted men, should reach Cape Hawks, if not Cape Collinson. Such action, from advice, experience, and observation, seems to me all that can be done to insure our safety. No deviation from these instructions should be permitted. Latitude of action should not be given to a relief party, who on a known coast are searching for men who know their plans and orders.*"*

This, the last paragraph of his letter to the Chief Signal Officer, which I have quoted in full, is very significant, and sufficiently explicit not to admit of any misapprehension. Greely also stated plainly that the vessel "*should not leave Smith Sound, near Cape Sabine, before September 15th.*" † At first the proposition to leave a party furnished with telescopes at Lifeboat Cove to watch the shore opposite, appears quite feasible until we come to consider the peculiar conditions of the atmosphere in the Arctic regions. If Greely had been an experienced Arctic traveller he would probably have devised some other plan ; for, sometimes it is impossible for several weeks in succession to get a glimpse of the coast of Ellesmere Land from the shore opposite. When the Polaris was beached on the 15th of October, 1872, the peaks of the coast to the westward were plainly in sight ; but from that time until the morning of February 9, 1873, they were completely hidden from view.

During the winter following the return of the Proteus from Lady Franklin Bay, a lively correspondence was carried on between the Chief Signal Officer and different parties, both here and in Europe, concerning the necessary supplies asked for by Greely in his various memoranda and dispatches.‡

On May 6, 1882, a board of three officers, none of whom had ever had any Arctic experience, met at the office of the Chief Signal

* Signal Service Notes, No. 10, p. 23. † *Loc. cit.*, p. 23.

‡ Appendix, p. 34 *et seq.*

Officer to consider the whole subject of the supply expeditions for Lady Franklin Bay, and also for Point Barrow, on the north coast of Alaska.* Two days later the Chief Signal Officer addressed the Secretary of War, stating that it was imperative to send at once an agent to St. Johns, Newfoundland, in order to charter a steamer of proper character; to employ an ice-master to be ready by July 1 to proceed to Lady Franklin Bay, with the outfit for the international Arctic station; and during the passage of the vessel to the north to obtain at some of the Danish colonies in Greenland those supplies needed by Lieutenant Greely, which could not elsewhere be procured. The Chief Signal Officer expressed the desire to send his personal secretary, Mr. Wm. M. Beebe, then a private in general service, and formerly an officer of merit on his staff during the war.† He also requested that the Secretary of the Navy should detail a naval officer, as had been done in 1881, to be ordered to St. Johns to assist Mr. Beebe in selecting a suitable vessel. On the 13th of May the Chief of the Bureau of Navigation ordered a Commander of the Navy to proceed to St. Johns, and, if necessary, also to Havre de Grace, to select a steam-sealer under instructions of the Chief Signal Officer of the Army.‡ Mr. Beebe had received his orders as early as May 8,§ but on the 12th of the same month Congress had not yet made the necessary provisions to fit out an expedition. The Chief Signal Officer was then absent at St. Louis, and James W. Powell, Captain, 6th Infantry, was acting in his place at the time. On the 12th of May he requested the Secretary of War to call the special attention of Congress to the fact that unless an appropriation was speedily made it would be impossible either to purchase the necessary supplies or to engage a suitable vessel to transport them, as sections 3679 and 3732 of the Revised Statutes forbade the execution of any contracts in advance of specific appropriation acts.|| On the same day Capt. Powell telegraphed to his chief at St. Louis that the Secretary of War determined that no contracts should be made for the relief expedition until the appropriation bill had passed. He informed him also that Mr. Beebe would leave for Newfoundland "next Tuesday," which, according to the almanac, was May 16.¶ On the 25th Mr. Beebe reported his safe arrival at St. Johns to General Hazen,** in a somewhat confused telegram, in which he said: "Last whaler leaves to-day,

*Special Order No. 53, Appendix, p. 39.

† Appendix, p. 40.

‡ Appendix, p. 41.

§ Appendix, same page.

|| Appendix, p. 42, No. 49.

¶ Appendix, p. 42, No. 50.

** Appendix, p. 48, No. 56.

and will not go direct to Greenland." According to Commander S. D. Greene's statement,* there were still five suitable vessels at St. Johns on the 27th of May, viz., the Proteus, the Neptune, the Bear, the Ranger, and the Hector. The Neptune was finally selected and chartered, and left on the 8th of July, under the command of a skipper named Sopp. Mr. Beebe, who meanwhile in the correspondence had been styled Major,† turned over the "instructions regarding observations to be taken on the voyage" to the said skipper; "but, as the instruments intended for this purpose could not be found, and as Captain Sopp evidently did not understand the nature of the observations ordered," Major Beebe transferred the duty to Private Joseph Palmart, Signal Corps, U. S. Army.‡ The only officer on board the Neptune was Dr. F. H. Hoadley, Acting Assistant Surgeon, U. S. A.

After having stopped at Disco, which place was reached on the 17th of July, the vessel on the 20th proceeded on her northward course. The season was evidently not an open one, and the weather was unfavorable. She passed Wolstenholme Island at eight o'clock on the morning of the 28th, and the Cary group at about seven in the evening. At 3.30 on the morning of the following day Littleton Island was passed, and the Neptune was fairly in Smith Sound. Half an hour later Major Beebe was called by the skipper, who informed him that it was impossible to proceed any farther. "Going at once on deck" (the Major says), "I found an unbroken ice-barrier, from twelve to twenty feet thick, extending from Cape Inglefield on the west across the sound to Rosse Bay and to the northern horizon, effectually checking our further progress."§ The vessel was therefore turned southward and found a good anchorage in Pandora Harbor. On August 7th, at 10.45, she resumed her northward course, soon encountering heavy ice; and on the morning of the 9th she was fairly beset, twelve miles from Victoria Head. During the next day she drifted a short distance to the northward, and then reached latitude 79°20 N., which may be called her highest latitude. On the 15th she was finally liberated and stood across the sound to the eastern shore; then she turned to the westward and came to anchor at Payer Harbor on the morning of the 18th. Subsequently the English depot was visited and found in good condition, with the exception of some casks of rum and wine which had been broken by bears. The cache was rebuilt and made as secure as possible.

* Appendix, p. 50, No. 59.

† Appendix, p. 43, note following No. 53, also p. 51, No. 60.

‡ Signal Service Notes, No. V., p. 5.

§ *Loc. cit.*, p. 7.

During the 21st and 22d small quantities of ice passed down the strait, and although a visit to the summit of Cape Sabine did not afford much encouragement, the vessel started to the northward at 1.30 P. M. on the 23d. North of Cape Sabine the coast was actually blocked; more to the eastward, however, some open water was found, through which the vessel worked her way in mid-channel till she was about due east of Cape Prescott; thence the ice extended to the northward as far as the eye could reach, stretching from shore to shore. Following the edge of the solid pack to the westward, she neared Cape Sabine, but the entrance of Payer Harbor was blockaded. The ship was then headed for Littleton Island and entered Pandora Harbor, where she remained till 3 o'clock on the afternoon of the 25th. In vain she now tried to penetrate north; after several desperate efforts she had to be moored to a floe. On the following day she made some northing, but, forty miles from Cape Hawks her progress was again checked by the pack. The ice was piled up in "huge, irregular rifts, impassable, even had they been stationary, by the trained seal-hunters who composed the crew; the idea of landing the stores by means of a sledge and boats was therefore abandoned." * On the 27th she proceeded some distance in a northerly direction, again reaching a position off Bache Island, but not nearer to the shore than before. The wind freshening from the northwest, the ship was made fast to a floe to wait for an opening. Notwithstanding the direction of the wind, the larger fields, many miles in extent, moved westward against it; when coming in contact with the shore, their course was changed to the southward until checked again by Cape Sabine and Brevoort Island. As all the ice in Smith Sound seemed to drift south in a body, it was determined to stand across once more to the eastward with a faint hope that an open lead might be found; but the result was the same as before. On the 28th the vessel therefore turned southward, anchoring off Littleton Island at 7.45 P. M. After the wind had abated, a party went on shore to select a place for a depot, but their presence was soon discovered by some Eskimos from Cape Ohlsen, and they therefore decided to postpone cacheing the provisions and stores till nightfall. They again stood across the sound, and at one o'clock on the morning of the 31st finally succeeded in effecting a landing and establishing a cache at Cape Sabine. The stores and whaleboat were placed in a sheltered spot, well secured and covered by a tarpaulin; and a tripod of scantling, with an oar

* Signal Service Notes, No. V., p. 9.

attached, to which pieces of canvas were nailed, was set up on the most prominent point close by. They then took refuge under the lee of Cape Ohlsen, as a heavy northeast gale was setting in. The gale continued unabated during the 1st, but at noon on the 2d of September they were able to leave their anchorage for a final effort to get farther north. Off Cape Sabine the same heavy ice-fields were encountered, and at eight in the evening the vessel had to be moored to a floe, where she remained till the 4th. Winter had now fairly set in and the young ice had increased to a thickness of four inches; the engineer reported a leak in the boiler; it therefore became necessary to return and establish a depot at Littleton Island without delay. The Eskimos still remaining on Cape Ohlsen, the stores were landed in a bight at the north end of the island, and were well concealed, while copies of records, with directions for finding the cache, were left at those points fixed upon by Greely the year previous. This being done, the last whaleboat was taken to Cape Isabella and its location marked by a tripod similar to the one on Cape Sabine.

At 11.40 on the evening of the 4th of September the vessel began her homeward voyage, and, after several stoppages, she reached St. Johns on the 14th of the same month.

Greely, foreseeing that the vessel he expected to be despatched in 1882 might probably not reach Lady Franklin Bay during the same season, requested the Chief Signal Officer, as has been previously stated, to send in the course of the following year a capable, energetic officer with ten men, eight of whom should have had practical sea experience, provided with three whaleboats and ample provisions for forty persons to last fifteen months, to effect his rescue. In consequence of this request, General Hazen, on the 27th of October, 1882, applied to the Commanding General, Department of Dakota, through the Adjutant-General of the War Department, "to select without delay an officer to take charge of half a dozen men to compose an expedition to proceed next spring to Lady Franklin Bay, as relief to the Greely Arctic party."* Ernest A. Garlington, Lieutenant, 7th Cavalry, having meanwhile volunteered to command the expedition, the Chief Signal Officer on the 13th of January, 1883, requested the Adjutant-General to direct him to report in person† at Washington. On the 20th of February the young officer arrived, and on the 28th of the same month Captain William H. Clapp, 16th Infantry, the chief

*Appendix, No. 116, p. 88.

†Appendix, No. 125, p. 93.

Arctic expert of the Signal Office, received a memorandum to the effect that he should give to Garlington the necessary information regarding the station at Lady Franklin Bay,* which request was complied with on the same day.

The preparations to fit out the expedition were at once commenced, and an Act of Congress, approved March 3d, provided for the completion of the work and made the regular annual appropriation of twenty-five thousand dollars. On May 10 General Hazen applied to the Secretary of War, asking for authority to proceed to St. Johns, in order to secure the best vessel available for the purpose ;† ten days later he received orders to that effect. Subsequently the steamer Proteus, which had conveyed the Greely party to Lady Franklin Bay in 1881, was chartered. At the request of the War Department the Secretary of War ordered the United States Steamer Yantic to act as tender to the Proteus, and Garlington with his men left New York on board the former vessel, commanded by Commander Frank Wildes, for St. Johns, Newfoundland, where they arrived on the 21st of June. While in St. Johns, Lieutenant J. C. Colwell, U. S. N., was at his own request detailed for duty to join the expedition, and reported to Garlington on the 23d of June. In the course of the afternoon of the 29th both vessels left the harbor for Disco Island, the Proteus once more in charge of her former skipper, Captain Pike.

Lieutenant Garlington had received his orders from the War Department on the 4th of June, and those of Commander Wildes are dated Navy Department, June 9. The Chief Officer very strongly urges the young Lieutenant of cavalry to spare no effort in pushing his vessel through to Lady Franklin Bay, as Greely with his party, unless reached by the relief ship, would have *to retreat southward by land* (!), and would thereby have to undergo great hardship and, perhaps, be compelled to abandon much valuable public property, with possible loss of important records and life. In case the vessel should be unable to reach her destination, Garlington was directed to land his party and stores at or near Lifeboat Cove, to discharge the ship with orders to return to Newfoundland, and to stay until relieved the following year. He should endeavor to communicate with Greely by taking personal charge of a party of the most experienced and hardy men, equipped for sledging, carrying such stores as would be practicable to Cape Sabine, where a smaller party, more lightly equipped, still

* Appendix, No. 136, p. 99.

† Appendix, No. 159, p. 113.

headed by himself, was to push as far north as possible or until the missing party were met.

The preceding paragraph embodies the substance of his instructions as given and signed by W. B. Hazen, Brig. and Bvt. Maj. Gen'l, Chief Signal Officer, U. S. A.*

The orders issued to Commander Wildes read to the effect, that in view of the possibility of the destruction of the Proteus, he should proceed as far north as practicable, to afford succor to her officers and men, in the event of such an accident, and that it was desired that he should await there the return of that ship, or the arrival of authentic information as to her fate. He should under no circumstances proceed beyond Littleton Island or enter the pack. The length of his stay to the northward of Upernivik was to depend upon his own discretion, and in case it should be imperative to leave the vicinity of Littleton Island or Cape York before the return of the Proteus, he was to establish a station on shore, having first settled with Lieutenant Garlington upon prominent points in Smith Sound or Baffin Bay in which to deposit information as to his movements.†

The agreement between Lieutenant Garlington, U. S. A., and Commander Wildes, U. S. N., was made in the shape of a memorandum, and reads as follows:

"Yantic will proceed to sea with Proteus and remain in company as long as possible. Yantic will proceed to Disco under sail. Will leave letters for Lieutenant Garlington at Disco and Upernavik. Cairns enclosing bottles or tins will be left at Cape York, NW. Cary Island, or Hakluyt Island, Pandora Harbor, and Littleton Island. Yantic will remain in Pandora Harbor not later than August 25th; Disco not later than Sept. 20th.

"Lieutenant Garlington to leave letters in Disco and Upernavik, and records on NW. Cary Island or Hakluyt Island, Littleton Island, and Pandora Harbor, if entered.

"Proteus to endeavor to communicate with Yantic at Pandora Harbor before August 25th.

"Should Proteus be lost, push a boat or party south to Yantic.

"Pandora Harbor will be headquarters, but before departure, Yantic will run up to Littleton Island."‡

The Proteus reached Goodhaven on the 6th of July and the Yantic on the 12th. As the latter vessel had to repair her boilers, the repairs causing

*Signal Service Notes, No. X., pp. 21, 22.

†Appendix, No. 241, p. 175.

‡Appendix, p. 117.

six days detention, the Proteus on the morning of the 16th* weighed anchor to proceed north and to procure a native dog-driver at a small settlement on Disco Fjord, on which occasion she ran foul of a rock, but was easily gotten off, without having suffered more damage than the breaking of her main injection pipe. On the morning of the 17th Hare Island was passed about 40 miles to the eastward, and at 6.20 P. M. Saunderson's Hope was sighted from a distance of some 50 miles. At 4.30 A. M. on the 19th the vessel had to stop on account of a heavy ice-pack; she was backed and put on a southerly course for about eight miles; then she steered to the eastward, and a little past seven high land was sighted. Up to this time it had been impossible to get observations; now a short stop was made on the edge of the pack to obtain sights for time, which placed the vessel in longitude 61° 30′ W. Captain Pike had pronounced the eastern land to be Cape York, while in reality it was Cape Walker. Unfortunately the data relating to geographical positions are very meagre in the official report of Lieutenant Garlington, and we find the same to be the case in consulting the log of the Proteus, as sent by cable from St. Johns to the New York *Herald* on September 17, although the article fills over two columns. On the track-chart, prepared under the direction of the Chief Signal Officer of the Army, accompanying "Signal Service Notes No. X.," the track of the vessel only begins at a point in about latitude 74° N., longitude 64° W., and continues due north to about latitude 76° N.; and it is not easy to make the graphic representation agree with the statements in Garlington's report as far as the passage through Melville Bay is concerned. After steering various intricate courses, Cape York finally came in sight during the afternoon of the 20th of July; at seven in the evening Conical rock was sighted, and six hours later it was passed, while the vessel was among loose ice. Towards midnight of the 21st the Proteus was stopped by close pack. At noon the following day she had cleared the ice, and subsequently the depot of the Nares expedition on the Cary group was visited and found to be undisturbed. According to Garlington's statement, about sixty per cent. of the provisions were in good condition, while perhaps seventy-five per cent. could be used in an emergency. After a record for the Commander of the Yantic had

*In comparing the report of Lieutenant Garlington with that of Commander Wildes we find a conflicting statement as to the time the Proteus sailed, Wildes' date being earlier by one day. See Signal Service Notes X., p. 5, and Appendix, No. 247, p. 178.

been left, the vessel steamed through open water, shaping her course to Cape Alexander. At 6 A. M. on the 22d the cape was doubled, and shortly afterwards she entered Pandora Harbor, where another document was deposited. There was no ice visible to the northward, not even from the crow's-nest. Garlington therefore determined not to stop at Littleton Island, but to push on to Cape Prescott, where he intended to establish his first cache and to leave a whaleboat. Littleton Island was passed shortly before ten in the morning, and the sea was still free from ice; but, half an hour later the lookout reported ice in sight, and towards noon the vessel was stopped by an apparently unbroken barrier, stretching from shore to shore and closing up the sound. Garlington then decided to proceed to Cape Sabine in order to examine the stores deposited there, and to leave records, and there to await further developments. Payer Harbor was reached at half-past three in the afternoon, and two privates were landed for the purpose of making magnetic and other observations. Garlington in person searched for the depot of provisions, which after some difficulty was eventually found; everything was in good condition except the boat, which had been slightly damaged by bears. While the men were at work he "examined the condition of the ice to the northward and discovered," as he states in his official report, "that the pack had broken, and that open lanes of water had formed, leading across Buchanan Strait, along Bache Island, and across Princess Marie Bay as far north as a point of land, which I took to be Cape Hawks, and around it. After satisfying myself with the glass that there could be no mistake about the presence of a favorable lead, I started back to the ship, hurrying as rapidly as possible, appreciating the rapid changes in the condition of the ice and the treacherous movement of the pack. I reached the ship at 6.30 P. M. and at once got the observers aboard, and told Captain Pike of the open way, and requested him to get under way and steam out of the harbor to make an examination of the leads and an effort to proceed north."*

Garlington, like a brave soldier, now availed himself of the first opportunity to carry out his orders and "*to push the vessel through to Lady Franklin Bay.*"† The master of the Proteus was opposed to proceeding farther north until the sound should be more clear of ice. It was still early in the season, and Smith Sound was scarcely navigable. But finally he was overruled by Garlington, whose orders had to be obeyed, and they weighed anchor. "In fifteen minutes

* Signal Service Notes No. X., p. 8.

†*Loc. cit.*, p. 21.

after leaving the harbor," according to Captain Pike's statement, "the ice was met, and the Proteus continued butting it until 3 P. M. next day, when she was jammed. At 7 P. M. she sank." *

Garlington, according to his own statement, requested Lieutenant Colwell to take station in the crow's-nest with the mate of the vessel, when Cape Sabine was doubled. His official report to the Chief Signal Officer contains the following passage relating to the movements of the vessel after having weighed anchor:

"We proceeded through the open leads in the broken ice, which was very heavy, to within four miles of Cape Albert, when the ship was stopped about six hundred yards from open water, which extended along the coast as far as could be seen from the 'crow's-nest.' Captain Pike thought the ship could be forced through, and entered a crack in the ice, and we accomplished about half the distance by 'ramming.' But after this the 'ramming' was ineffectual, as the fragments of ice about the ship had become ground up so fine that when she backed out, it would fill up the space immediately in front of the new fracture in the ice, and, as the ship came forward to ram, it acted as a cushion, which reduced her momentum to such an extent that when she struck the ice itself she had not sufficient force remaining to have any effect upon it. About midnight the attempt at this point was given up. A lead was found more to the eastward, in which the ship made fair progress until 2 A. M. the 23d, when we were jammed and unable to move in any direction within two hundred yards of open water. The ice here was not so heavy as it was in the position left at midnight, and Captain Pike pronounced the ship in no danger, on account of its yielding nature. Soon after, at 5 A. M., the ice immediately in front separated, and we were in the open water, which had been in our immediate front the night before. On

*_Evening Mercury_, St. Johns, Newfoundland, Sept. 21, 1883, p. 2.

On the 27th of December Captain Pike stated before the Court of Inquiry, convened at Washington, D. C., pursuant to General Order No. 249, of the War Department, as follows: "We entered Payer Harbor, I think, about 5 o'clock, and anchored, and about 7 o'clock Lieutenant Garlington came on board. I was lying in my bed, and he came to the stateroom door and called me and told me he could see open water away north towards Cape Hawk. I told him I didn't think it was any good and that I was not ready to go; I wanted to get some fresh water and fill my bunkers. I also told him I was anxious to get north as he was. He says, 'I can see open water, and I want to go,' and said, 'You shall have my men to help fill your bunkers.' I said I would go, and we left there about 7 o'clock in the evening, or half-past seven."

arriving within four miles of Cape Albert it was discovered that the open lane of water seen the night before had disappeared, and that the solid pack now held its place."

Were I treating this as a mathematical problem, I should give the greatest weight to the judgment of Captain Pike; the next weight would have to be given to the opinion of Lieutenant Colwell, who, at the time, was in the crow's-nest; and I should give the least weight to the opinion of Lieutenant Garlington. To battle successfully the ice in the Arctic seas is somewhat different from leading a dashing cavalry charge, and, similarly, the anatomy of a horse is somewhat different from that of a vessel. Besides, we can hardly expect a young lieutenant who has distinguished himself on the plains, to have the experience of an ice-master, grown gray in the service. The Proteus is now at the bottom of the sea, and all the arguments I could offer would not be able to raise her, or to relieve the ice-bound party in Lady Franklin Bay. The person responsible for the disaster is the Chief Signal Officer, who had sent a young lieutenant of cavalry on a mission that ought to have been entrusted to an experienced Arctic explorer. In 1882 he sent an individual who was not sober during the voyage as long as the liquor lasted; and, according to the statements published in the leading newspapers, the same person would have again been detailed if steps had not been taken to prevent it. If the Chief Signal Officer was determined to follow Greely's instructions and send an officer of the service, why did he not select Captain Clapp, who had given considerable study to Arctic explorations, and who had volunteered to go and take charge of the party? Captain Clapp had officially requested the Chief Signal Officer to send him, and for a time was hopeful of going; but to his request he never received any reply, either written or verbal.* The Chief Signal Officer evidently treated the whole matter with too much indifference, and his ideas as to the safety of Greely and his command seem to have undergone considerable change in a very short time, as may readily be inferred from the official documents published in the Appendix of his Report.† In his Annual Report to the Secretary of War, for the year 1883, we read the following passage: "*If the 'Proteus' shall not reach Lady Franklin Bay, an application will be necessary for another expedition to sail in 1884, for, no special appropriation had been made*

* See Captain Clapp's letter, dated Camp Pinery, near Fort Davis, Texas, December 1st, 1883.—Proceedings of the Court of Inquiry, pp. 181–83.

† In Appendix, p. 82, No. 110; p. 88, No. 117; p. 118, No. 175.

by Congress except for the expedition that sailed in 1883." The date of his report is October 15, 1883; the loss of the vessel was telegraphed from St. Johns on the 13th of September, and Garlington reached Washington on the 1st of October, and reported at the office of the Chief Signal Officer for duty. It is true that the report is for the fiscal year which ends June 30; but extraordinary circumstances require extraordinary measures.

The idea expressed by General Hazen that Greely and his party would have to retreat overland in case of emergency is certainly a very peculiar one, and it clearly shows that those who wrote Garlington's orders were utterly ignorant of the nature and character of the country to be traversed. The orders were evidently written by a soldier; and in Arctic exploration, as in warfare, the topography of the country to be passed over is of primary importance.

In 1728 the Danish government sent Major Paars and Captain Landorff to West Greenland, in charge of a company of soldiers, with horses and artillery-pieces, and with orders to cross to the ice-bound east coast to establish a fort.* The two officers named had proposed to traverse the country on horseback, but the horses died during the passage and the artillery was then rendered useless. When the party became acquainted with the true character of Greenland, they noticed at once what a ludicrous and madcap scheme they had advocated. This happened more than one hundred and fifty years ago, when very little about the topography of Greenland was known. To-day we can only smile at such an attempt.

But let us now return to the wrecked crew of the Proteus. Lieutenant Garlington with his men had been helping to take stores on deck after the vessel had been nipped, and had the provisions and most of the instruments of the expedition placed on the ice. Lieutenant Colwell, having stuck to the Proteus till the very last, succeeded in landing some of the stores about three miles west of Cape Sabine, and secured them as well as circumstances permitted. This cache consisted of hard bread, of tea and bacon, of canned goods, sleeping-bags, and tobacco. It was estimated at five hundred rations. Soon after Lieutenant Colwell had started for Cape Sabine, Lieutenant Garlington followed him; but the passage was very tedious; he had only two men who were familiar with the use of oars, and the boat was almost swamped. At noon of the 24th of July the whole party was

* See Robert Brown, Arctic Papers, p. 6.

on shore at Cape Sabine with about forty days' rations. They cached a large quantity of clothing, and left soon after three o'clock in the afternoon of the following day, to open communication with the Yantic, or perhaps with the Swedish steamer Sofia. In crossing the sound, the boats were separated during a fog. Garlington with his two boats remained over night near Lifeboat Cove, and early the next morning reached Pandora Harbor, where he found Captain Pike with the rest of the party. Proceeding south, they made land on the evening of the 8th of August about fourteen miles north of Cape York; shortly afterwards, the ice was closely packed. Lieutenant Colwell, with orders to proceed south, left in a boat manned by volunteers early in the morning of the following day, to communicate with the Eskimos at Cape York. Towards midnight, after the ice had opened, the rest of the party also started. When eight miles from Cape York, their attention was attracted by the report of a rifle fired on shore. They immediately steered for the point whence the sound had proceeded, and in a few minutes reached Colwell's camp. Through the interpreter he had ascertained from the natives that as yet no vessel had passed. The Yantic had left Upernivik only at noon on the 31st of July, and did not sight Cape York until one o'clock in the morning of the 20th of August. Towards ten in the evening she reached the Cary Islands and found Garlington's record. She left an hour afterwards with no ice in sight, and passed Hakluyt Island at two o'clock the following morning. Commander Wildes then steered for Cape Alexander, where he arrived at one o'clock in the afternoon, finding the ice closely packed against the land, while there was some open water on the opposite shore. At Littleton Island he picked up another record of Garlington from a small cairn in which he deposited some documents relating to the course of the vessel, and at 10 P. M. he was at anchor in Pandora Harbor, where two more cairns were discovered: one, from Captain Pike, with news that the party were proceeding south, hoping to meet the Yantic; the other, from Lieutenant Garlington, stating that he had arrived at Pandora Harbor on the 26th of July. Commander Wildes at once got under way and, passing Cape Alexander, steered down the coast to Cape Robertson within a mile of the beach, looking out for cairns or other traces of the Proteus men. Nothing was seen, however, and, passing Cape Robertson, he ran across the mouth of Murchison Sound and skirted the shore of Northumberland Island. Then he stood across to Hakluyt Island, which was closely examined, and after-

wards he searched the cairns of the Cary group. Unwilling to leave without obtaining news from the missing party, Wildes returned to Hakluyt Island, the SE. point of which was passed August 5, and stood across Whale Sound. At a low point two miles east of Cape Parry he deposited a record and then proceeded to the south. In the evening of the next day the Yantic anchored at Northumberland Island, where the parties sent on shore discovered two broken-up camps, only a few days old. Commander Wildes, feeling certain that the crew of the Proteus had proceeded south, concluded to follow the same course as soon as the condition of the ice would permit. After having erected a cairn in which he deposited a record, he left at 3 P.M. on the 9th of August, and stood southward to continue the search. In the evening, the pack, extending in a northwesterly and southeasterly direction, was reached. The vessel was headed for Cape York, and after several detentions, caused by ice and thick weather, finally anchored at Upernivik on the 12th. Shortly afterwards, the commander of the Yantic chartered a launch from the chief trader of the settlement, and dispatched it to Tassiussak with fifteen days' rations for thirty-seven men. He remained at Upernivik till the 24th and proceeded to Waigat, where he spent four days in coaling, making Disco on the 28th. Early on the morning of the last day of August a native arrived in a kajak with a letter from Lieutenant Colwell, and shortly afterwards Colwell himself came with six men and an Eskimo. Colwell had reached Upernivik only a few hours after the vessel had sailed; he stopped merely long enough to dry his clothing and to embark in a launch, when he started for Disco. He had been in an open boat for thirty-nine days, and under great hardships and privations had travelled some 900 miles. Having separated from the other boats at Cape York, he took the first open lead in a southeasterly direction, intending to steer to Upernivik; but he was hardly under way when a westerly gale set in, before which he had to run for about twenty hours. This was immediately followed by another gale from the southeast, which was ridden out under the lee of an iceberg. Even under the most trying circumstances his crew showed unfailing courage, and were always in readiness to comply with any call of their commander, who displayed more than ordinary energy, courage, and professional skill.

Thinking that the other boats had reached Upernivik, Commander Wildes proceeded there on the afternoon of the same day, and on the 2d of September had the gratification of welcoming the whole party

on board his vessel. Although somewhat thin and weather-beaten, they were all in good health, with the exception of the surgeon, who suffered from sore feet. Near Cape Shackleton, Lieutenant Garlington had met a number of Eskimos in a whaleboat, who gave him some hard bread and coffee. The man in charge of the boat was from Upernivik; he understood a little English, and informed Garlington that he had been ordered to look out for him and his party, and that Wildes had sent stores to Tassiussak. They all proceeded to the latter place, where they arrived in the afternoon of the 23d of August. A letter from Commander Wildes, written at Upernivik ten days before, stated that he would remain there as long as he considered it prudent, and would then proceed to the coal mine near Disco. Subsequently the party set sail for Upernivik, although Captain Pike's men insisted upon making a halt; they reached that settlement in the course of the forenoon of the following day, and were most kindly received by the hospitable Danes; the officers were invited to live at their dwellings, while the chief trader of the post had cleared a comfortable storehouse, belonging to the Danish Company, to serve as quarters for the men. Here Garlington also received some news about Colwell, and learned that he had left on one of the launches belonging to the company. A letter left by Wildes informed him that he considered it "a serious risk to keep the vessel in this high latitude," and that he would "remain at Godhaven until about September 15th, not later, and then proceed home." *

Garlington had decided to await news from the Yantic at Upernivik, to winter there in case she should fail to return, and to make a sledge journey to Cape York. This proves that Garlington could not have been familiar with the condition of the ice in Melville Bay. Eskimo Hans, who had deserted Kane's vessel, although thoroughly homesick and well acquainted with most of the northern Danish settlements in Greenland, did not even attempt to start south, but patiently awaited the appearance of a vessel, and after years of longing was finally rescued by Hayes.

The mistake had been made; the Proteus had gone down, and there was evidently nothing to be done but to return home. On the 13th of September the Yantic reached St. Johns, Newfoundland, and arrived at New York on the 29th of the same month.

Serious charges have been made by various parties against Lieutenant Garlington and Commander Wildes. But it must be remem-

* Signal Service Notes, No. X., p. 17.

bered that the Yantic was not built to encounter heavy ice or to enter the Arctic pack; and her commander would therefore not have been justified in taking any more risks than he did; had he done so, we might now have to deplore the loss of two vessels instead of one. If the Proteus had waited in Payer Harbor for a week or ten days, Smith Sound would probably have been more open, and she might have passed with impunity the critical place where the Neptune was beset the year before, and where, a short distance to the south, she herself was nipped and lost.

The two officers above-named have certainly tried to fulfil their mission to the best of their knowledge and ability. A Newfoundland sealer or a whaling vessel of the fleet, built for the purpose, might easily have stayed in Smith Sound till the 15th of September, as requested by Greely in one of his memoranda sent back to the Chief Signal Officer from Camp Conger after the party had been landed. But the Yantic could not do so, and the disaster that happened to the Proteus could not be foreseen, and would certainly not have happened had Garlington not ordered her skipper to plunge headlong into the ice. The answer he received from Captain Pike, when he ordered him to go ahead, that "the coal-bunkers of the vessel were not filled," may be considered as a mere pretext, because the experienced sailor hesitated to go and wished to await a more favorable opportunity in order to proceed north. Garlington, as mentioned before, acted like a brave cavalryman and tried to obey strictly his orders, and "*to push the vessel through to Lady Franklin Bay.*" He attempted to carry out these orders and wholly disregarded his so-called "supplementary instructions," so often spoken of lately, and which were found by him enclosed in an envelope that contained his actual instructions. He had considered these supplementary instructions to be merely an authenticated copy of a memorandum prepared in the office of the Chief Signal Officer for the Secretary of the Navy, and to be simply the basis of instructions to be given to the commander of the vessel ordered to accompany the Proteus. Garlington at once carried the document to the Chief Signal Officer and called his attention to the clause relating to land stores and supplies on Littleton Island. The Chief Signal Officer said that he did not know how the document had found its way into the envelope containing Garlington's orders, and impressed him with the necessity of simply carrying out those orders properly addressed to him.

The main paragraph of the supplemental orders reads as follows:

"*The Proteus is to land her stores, except supplies for more northerly depots, at Littleton Island on her way north. If she succeeds in reaching Lady Franklin Bay, she is to pick up the stores, excepting the house and depots, if possible, on her return.*"

If this paragraph had been incorporated in the *orders* and *instructions* officially sent to Garlington, much anxiety and sorrow would have been spared those interested in the welfare of the party, and in Arctic exploration in general.

The position of Greely and his party is not a dangerous one, although it is critical. He probably has provisions sufficient to last until the autumn of 1884, without taking the fourteen musk-oxen into consideration; these, according to his own statement, would provide him and his men with meat for seven months, even though issued as often as three times a week. Captain John Ross, not as well equipped as he is, spent four consecutive years in the Arctic regions, and still made good his retreat; but at the same time we must not forget that he wintered in lower latitudes, where the sun is not so long below the horizon as in Lady Franklin Bay. The news received from the Cape York Eskimos by the Swedish steamer Sofia, that, according to the statement of the Eskimo Hans, one of the members of the Greely party had been killed, ought not to be credited. These people are fond of telling stories in order to make themselves interesting. If the two natives in Greely's employ had actually come south from Lady Franklin Bay, they would either have been the bearers of despatches which they would have deposited in the various cairns erected by the party, or they would have returned to one of the Danish settlements. There exists another version of the story to the effect that some white men had come from Lady Franklin Bay to Littleton Island, who are said to have informed the natives of a similar occurrence. As far as I am aware, there was no white man with Greely who was familiar with the language of the Eskimos, and the Eskimo language is not easily acquired; if these white men had reached the mouth of Smith Sound, they would certainly have visited some of the depots and would have tried to get on board of one of the whalers.

I consider it probable that Greely with his party did not leave Lady Franklin Bay after the vessel had failed to reach them. In the course of time they evidently learned how difficult it would be to make a sledge-journey to Littleton Island from Fort Conger. They

had certainly become acquainted with the character of the ice of Smith Sound after they had set out on their autumn travels; and, after having spent a few days only at their wintering place, they would have learned that a retreat overland as mentioned by the Chief Signal Officer would be an impossibility.

If Greely had attempted to retreat, he could have fallen back on the various depots established by the English Expedition, by himself, and by the two relief expeditions sent out in 1882 and 1883. Major H. W. Feilden, H. B. M. A., who had highly distinguished himself as naturalist of the Alert, under Sir George Nares, says, in a letter to me, dated Wells, Norfolk, November 5th, 1883: "I have no doubt that the United States Government with its usual energy and munificence will organize relief next year on an efficient scale." He is of the same opinion as myself that Greely had not left Lady Franklin Bay; but he takes a less favorable view of the case, not knowing that the party is provided with stores sufficient to last them till the autumn of 1884. Major Feilden, assuming the party to be still ice-bound, proposes to have a relief-expedition sent out next year, consisting of two steamers, and continues: "The coast-line from the Devil's Thumb to Cape York should be searched in case the Eskimo report be true that Greely's party reached Littleton Island and attempted to get south. The search should be carried along carefully from Cape York to Littleton Island. Supposing that one steamer did that, the other might go on to Pandora Harbor or Port Foulke. Premising that both our ships are at Port Foulke in the beginning of August, I would suggest that they move across the Sound to Payer Harbor; one, to remain there, the other, to be ready to take advantage of any clearance in the ice so as to make a rush up to Discovery Bay. Supposing that this proves impossible, then I am afraid the fate of Greely's party would be sealed; the winter of 1884–85 would be beyond hope. Still, it would be incumbent to recover the records and to see to the fate of the Discovery Bay party. To this end (the necessity I trust may never come to pass) one ship should be left to winter in Payer Harbor and from thence push sledge-parties to Discovery Bay in the spring of 1885. The escape of a steamer from Payer Harbor in 1885 is almost a certainty."

So far Major Feilden, whose opinion is of great weight. Personally I feel inclined to take a more favorable view of the case, and do not hesitate to express the hope that Greely, towards the end of June, will be near Littleton Island. But at the same time I will

not omit mentioning that a party who has spent three winters in the latitude of Fort Conger is probably not over fresh. The sick ones will have to be cared for and will have to be conveyed south, and there will be other drawbacks; the bad condition of the ice, the stormy days necessarily to be expected, and the low temperatures necessarily to be encountered. Although I consider it more prudent to send two vessels, one would be sufficient to relieve the little band. A staunch steamer, built for ice navigation, and well equipped, provided with dogs, sledges, and the other necessaries for an Arctic campaign, and provisioned for two years, should leave the United States early enough to reach the edge of the pack in Melville Bay about the middle of June, or perhaps earlier, so as to be ready to take advantage of an unusually open season. She should search the vicinity for traces of the missing party, and then proceed northward, perhaps to Littleton Island, Port Foulke, and then to Payer Harbor. She should carry an additional number of whaleboats; for, if Greely should not have come south, a boat journey to Fort Conger could be made much more easily than a cruise in a vessel. It would be advisable to procure some Umiaks at the Danish settlements in West Greenland, for an Umiak is very portable. These boats are flat-bottomed, from 25 to 37 feet long, about 2½ feet deep, and 5 feet beam, and in bad weather they almost equal a whaleboat, as their flexibility prevents them in some measure from shipping seas.* Laden with provisions for the voyage north, they might be taken in tow by the whaleboats, and finally be cut adrift after the provisions had been consumed; or, if possible, they might be cached on shore, near the various depots, which should be left intact for the joint retreating party. Captain W. A. Graah, of the Danish Navy, during the years 1828 and 1831, explored the ice-beleaguered east coast of Greenland to about latitude 65° N. in these boats, and, as usual, they were rowed by women, and did excellent service.

In the way of suggestions I have nothing more to offer, for the navigation of the Polar seas is uncertain, and depends solely on the favorable condition of the season and on the natural tact of the sailor. But if Government should decide to purchase one or more vessels for the relief of the Greely party, these vessels ought not to be disposed of as was the Tigress in 1873, which, after having returned from her searching expedition, was sold to her former owners at a sacrifice.

Countries comparatively poor, like Scandinavia, Germany, and

* Rink, Danish Greenland, p. 179.

Holland, own vessels especially fitted out for Arctic exploration, and the short summer voyages of these vessels have largely added to our present knowledge of the Polar seas. Why should the United States not follow the example of these countries? A private English gentleman, Mr. Leigh Smith, owned a yacht on which, at his own expense, he made yearly voyages to the Arctic regions, and to his various unpretentious cruises we owe valuable geographical discoveries. Why then should a great country like the United States not be able to do what a private individual has accomplished? why should it not follow the example of countries whose coast-line is almost microscopic, if compared with the coast-line of North America? Hydrography is the key to navigation, and navigation controls commerce and traffic, which, in their turn, regulate the welfare of nations.

The various failures and disasters we have to record in Arctic explorations during the past few years should not tend to dishearten us. On the contrary, they should intensify our interest, and increase our efforts to unveil the secrets of the Poles. Arctic exploration, like warfare, has in the course of time fairly become a science, and the danger of now wintering in high latitudes is much less than it was twenty years ago. Our resources are growing, and they do so at an almost astonishing rate. The percentage of lives lost in Arctic exploration is insignificant when compared with the mortality in the tropics or in other regions, where contagious diseases sometimes in a single day carry off more victims than death reaps in half a dozen Arctic exploring vessels during the course of years. And what a splendid school for seamanship the Polar seas afford, where the sailor has constantly to be on his guard; where ice-floes, moved by treacherous currents, may at any moment endanger and nip his vessel and send her to the bottom of the sea! Polar exploration heightens the courage of the sailor and cultivates presence of mind, thereby raising the moral standard. Nelson, the hero of Trafalgar, had seen Arctic service under Phipps during his voyage towards the North Pole in 1773, and Cochrane probably owed no small part of his naval success to his experience in the Polar regions.

The nineteenth century, with its great inventions and discoveries, is drawing to its close, and in geography a new era has commenced; but, our knowledge of the distribution of land and water in the vicinity of the Poles is almost as imperfect as it was at the time when Cook made his memorable voyage towards the South Pole, and when Forster, his scientific companion, tried to convince him that the vast ice-floes obstructing their passage were not of meteoric origin.

NOTES.

The map accompanying this paper is a photo-lithographic reproduction of the map contained in Bessels' *Amerikanische Nordpol Expedition.* Originally it showed only the tracks of the Polaris Expedition ; the others were subsequently drawn in. As the sheet had to be greatly reduced, and as confusion would thereby be avoided, I omitted the tracks of those vessels that could not strictly be termed exploring vessels. The plan of Discovery Harbor, which was also added, is copied from the plate facing p. 62 of the English Blue Book, containing the account of the expedition under Sir George Nares of 1875–76.

The material of the preceding paper, which does not claim to be much more than a critical compilation, was taken from the works mentioned hereafter. I have drawn freely from the publications of the various explorers, going in some instances so far even as to use their own words, when I thought that I could attain a higher degree of accuracy. With regard to the voyage of Bylot and Baffin, I had an opportunity several years ago to consult the original manuscript in the British Museum, and I have used my notes, made at the time. Inglefield's narrative I have not been able to see in the original, as I found it impossible to purchase or otherwise obtain a copy of this work. As the compiler and editor of the voyage of the Polaris had only a few meagre journals and a log-book at his disposal, I have dwelt somewhat longer on the passage of the vessel and upon the more important incidents during the voyage ; frequently I have used entire passages from my own narrative.

The works enumerated hereafter have been consulted and partly quoted. For the sake of brevity, the Appendix to the Report of the Chief Signal Officer is merely quoted as "Appendix," and the Narrative of the Polaris, edited by Admiral Davis, as "Narrative."—

Arctic Manual, prepared for the use of the Arctic Expedition in 1875, under the direction of the Arctic Committee of the Royal Society, edited by Professor T. Ruppert Jones. London, 1875.

Arctic Papers for the Expedition of 1875. London, 1875.

Bessels (Emil). The Tides at Polaris Bay. Washington, 1876.

——Scientific Results of the U. S. Arctic Expedition. Washington, 1876.

——Die Amerikanische Nordpol Expedition. Leipzig, 1879.

Beynen (L. R. Koolemans). De Reis der Pandora. Amsterdam, 1876.

Davis (C. H., Rear-Admiral, U. S. N.). Narrative of the Polaris Expedition. Washington, 1876.

Feilden (H. W.). Notes from an Arctic Journal. (Reprinted from "The Zoologist"),—no date.

Graah (W. A.). Undersögelses-Reise til Östkysten af Grönland, 1821–31. Kiöbenhavn, 1832.

Hayes (Isaac I.). The Open Polar Sea. New York, 1874. Hurd & Houghton.

——An Arctic Boat Journey in the autumn of 1854. Boston, 1860.

——Physical Observations in the Arctic Seas, reduced at the expense of the Smithsonian Institution, by Ch. A. Schott. Accepted for publication, February, 1865.

Howgate (Henry W.). Polar Colonization and Exploration. Beresford, Printer, 523 Seventh Street, Washington, D. C. (no date ; probably published in 1877).

——Congress and the North Pole. An abstract of Arctic Legislation in the Congress of the U. S. Kansas City Review of Science and Industry, 1879.

——The Cruise of the Florence. Washington, D. C. James J. Chapman, 1879.

Kane (Elisha Kent, U. S. N.). The U. S. Grinnell Expedition in search of Sir John Franklin. New York, 1854.

——Arctic Explorations ; the second Grinnell Expedition in search of Sir John Franklin, 1853, '54, '55. Philadelphia, 1856.

——Physical Observations in the Arctic Seas, reduced by Ch. A. Schott. Washington : Smithsonian Institution, 1859, 1860.

Markham (Albert Hastings, Captain R. N.). The Great Frozen Sea. London : 1878.

Nares (Sir G. S., Capt., R. N.). Narrative of a voyage to the Polar Sea during 1875–76 in H. M. Ships "Alert" and "Discovery." London, 1878.

——Official Report to the Lords Commissioners of the Admiralty. Nature, November 9, 1876, pp. 24–48.

Navy Department. Annual Report of the Secretary of the Navy on the operations of the Department for the year 1873. Washington, 1873.

Petermann (A.). Das Nördlichste Land der Erde. See Petermann's Geographische Mittheilungen, 1867, Heft 5, p. 176–200.

Signal Service Notes, No. V. Work of the Signal Service in the Arctic Regions. Washington, 1883.

——Notes No. X. Report on Lady Franklin Bay Expedition of 1883. Washington, 1883.

——Annual Report of the Chief Signal Officer to the Secretary of War for the fiscal year ending June 30th, 1881. Washington, D. C.

——Appendix to forthcoming Annual Report of the Chief Signal Officer. (This Appendix was printed for the use of the Proteus Court of Inquiry, pursuant to Special Order No. 249, and my quotations are taken from the advance sheets. They were paged from 1 to 242.)

Rink (Dr. Henry). Danish Greenland ; its people and its products. London, 1877.

Ross (John, Captain Royal Navy). A Voyage of Discovery for the purpose of exploring Baffins Bay, and inquiry into the probability of a Northwest Passage. London, 1819.

War Department. Various printed Orders and Instructions.

Weyprecht (Karl). Die Metamorphosen des Polareises. Wien, 1879.

Young (Sir Allen, R. N. R.). The Two Voyages of the Pandora in 1875 and 1876. London, 1879.

Navy Department. Annual Report of the Secretary of the Navy on the operations of the Department for the year 1873. Washington, 1873.

Those who study the above-mentioned publications in a critical manner will probably come to the conclusion that my *Amerikanische Nordpolfahrt* contains

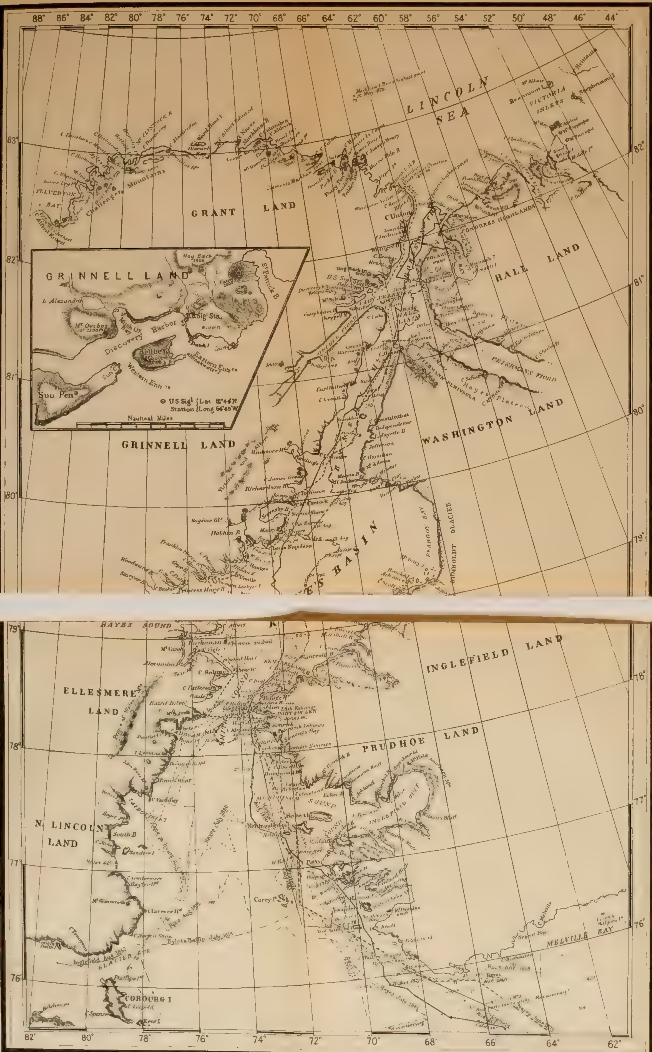
a number of woodcuts, evidently taken from the *Narrative*, without my stating the source from which they were derived. This, however, is not the case, as these illustrations were placed by me at the disposal of the editor of the *Narrative* and belong to me. I herewith give the pages of the illustrations as found in the *Narrative* and also as found in my own book. The pages in the upper line, in heavier type, are those of my work; those in the line below relate to the *Narrative*.

158	**455**	**239**	**297**	**449**	**320**	**223**	**34**	**442**	**67**
43	66	86	106	138	170	214	223	271	316
180	**419**	**117**	**404**	**254**	**428**	**315**	**283**	**349**	
333	363	464	496	519	554	576	593	621	

But the late Rear-Admiral C. H. Davis, U. S. N., the editor of the *Narrative*, cannot be held responsible for this oversight. The pages of this book had not yet gone entirely through the press when his health was failing, and the final revision and correction of Chapters XIX. to XXV., and consequently of the tables of contents also, were entrusted by him to Professor J. E. Nourse, U. S. N., who subsequently edited the narrative of *Hall's Second Arctic Expedition*. This volume, a typographical masterpiece, printed on excellent paper, contains also a considerable number of my woodcuts, which I had placed at the disposal of Professor Nourse. Those on the following named pages are my property: Ptarmigan, p. 71; Eskimo sled, p. 85; Eskimo games (ball and cup), 2 figures, p. 96; dog-skin mittens, p. 107; lance, and parts of the same, 4 figures, p. 121; seal-skin boots and bear-skin mittens, 2 figures, p. 136; harpoon heads, 2 figures, p. 169; ivory and bone combs, 2 figures, p. 177; deer-skin gloves, p. 213; Kajak ornament, p. 216; Eskimo sled, p. 221; bear-tooth toggle, p. 295; snow-goggles, p. 343; seal and deer-skin foot-gear, 4 figures, p. 380; snow-shovel, p. 392; stone pot, p. 408.

They comprise twenty-six illustrations, a considerable percentage of the illustrations contained in the volume. The greater portion has been published in my narrative; a number of others have not yet been printed, and I must guard myself against the suspicion of having plagiarized from the work of Professor Nourse. To avoid further mistake, I consider it my duty to mention that this gentleman placed a number of my illustrations at the disposal of the Rev. Sheldon Jackson, who used them in his "Alaska," published at New York by Dodd, Mead & Co., without date. All those representing ethnological specimens, the originals of which are, without any exception, in the collection of the U. S. National Museum, are not from Alaska, as stated by the Rev. Mr. Jackson, but mostly from Greenland or the Parry Archipelago.

SMITH SOUND AND VICINITY.



NAVAL INSTITUTE, ANNAPOLIS, MD.

April, 1884.

THE CRUISE OF COLUMBUS IN THE BAHAMAS, 1492.

By Lieutenant J. B. Murdock, U. S. N.

It devolved on me a year ago to review for the Naval Institute the monograph of the late Hon. G. V. Fox on the Landfall of Columbus. I became interested in the subject and gave it careful study; but, while appreciating the conscientious care shown in the preparation of the monograph, I could not agree with the conclusions reached. I was led to believe that different conclusions were better supported by the evidence, and therefore prepared a paper setting forth what seemed to me a more natural deduction.

Owing to the number of articles of immediate interest furnished to the Institute, this paper has not been published until now.

In no respect did Mr. Fox show more clearly the earnestness and conscientiousness of his search than in his examination into all possible records that might throw light on the cruise of Columbus among the Bahamas in 1492. The principal authority is of course the log of Columbus himself; but the old Spanish annals afford information on many doubtful points, and the cartographers of the sixteenth and seventeenth centuries have supplied abundant material for reference. Mr. Fox searched these diligently, and endeavored to extract truth from the mass of error incorporated in the old charts; but the task seems wellnigh hopeless. In all probability the Bahamas were but little known until long after the time of Columbus. The discovery of Cuba and the conquest of Mexico and Peru diverted the tide of travel to the southward of the Bahama group. In comparison with the rich and fertile West Indies, these islands were of little importance, and were but little visited. The data on which to make accurate charts were therefore insufficient, even if accurate methods of locating isolated islands had then been in vogue. It is only within the present century that good charts of the Bahamas have been produced, and a

comparison between these and the ancient ones discloses little resemblance. An inspection of such of the latter as were accessible induced me to believe that better results would be obtained by wholly ignoring the old charts (which differ so widely among themselves as to afford support to almost any theory that might be suggested), and by comparing Columbus' own statements of the islands he visited with the best *modern* charts procurable. Both these authorities seemed reliable, and my investigation has been based on a comparison between them.

Mr. Fox's monograph contains the original Spanish of Columbus' journal as transcribed by Las Casas, and a verbatim translation by Mr. Thomas of the United States State Department. Incorporated in this paper is a translation by the late Prof. Montaldo of the United States Naval Academy, which is a revision of that given by Mr. Thomas. The fact that Prof. Montaldo was instructor in Spanish at the Naval Academy nearly twenty years, during which time he gave special instruction in Spanish nautical phraseology and in the English equivalents of technical terms, renders him specially qualified to decide on many of the doubtful terms contained in Columbus' journal. I am greatly indebted to him for explanations of many obscure points, and have in all cases deferred to his authority. The responsibility of the track hereafter suggested as that of Columbus is, however, entirely mine.

It must be premised that the journal contains statements that appear to be absolutely irreconcilable with the present topography of the Bahamas. It is possible, but improbable, that since 1492 sufficiently great changes in the size and position of the islands have taken place to explain these statements. Attention is called to these as they occur. Five tracks have been suggested as followed by Columbus from San Salvador to Cuba, these tracks beginning at five different outlying islands. The diversity of these tracks may be seen from the following table:

Names given by Columbus.	Islands corresponding thereto according to				
	Navarrete.	Varnhagen.	Irving.	Becher.	Fox.
San Salvador	Grand Turk	Mariguana	Cat	Watling's	Samana Cay
Santa Maria	Caicos	Acklin	Concepcion Cay	Long	Crooked
Fernandina	Little Inagua	Long	Exuma	Exuma	Long
Isabela	Great Inagua	Crooked	Long	Crooked	Fortune
Islas de Arena	...	Ragged	Mucarras	Ragged	Ragged
Cuba	Cuba	Cuba	Cuba	Cuba	Cuba

The journal of Columbus being taken as final authority, the translation kindly furnished by Prof. Montaldo is as follows:

Wednesday, October 10.

He sailed west-southwest, at the rate of ten miles an hour and occasionally twelve, and at other times seven, running between day and night fifty-nine leagues; he told the men only forty-four. Here the crew could stand it no longer; they complained of the long voyage, but the Admiral encouraged them as best he could, giving them hopes of the profits that they might have. And he added that it was useless to murmur, because he had come to [in quest of?] the Indies, and was so going to continue until he found them, with God's help.

Thursday, October 11.

He sailed to the west-southwest; had a high sea, higher than hitherto. They saw pardelas, and, floating by the vessel, a green rush. The men of the Pinta saw a reed and a stick, and got a small stick apparently cut or worked with an iron instrument, and a piece of cane and some other grass which grows on the land, and a small board. Those of the caravel Niña also saw other indications of land and a little stick loaded with dog-roses. In view of such signs they breathed more freely and grew cheerful. They ran until sunset of that day twenty-seven leagues. After sunset he sailed on his first course to the west; they went about twelve miles an hour, and two hours after midnight they had run about ninety miles, that is, twenty-two and a half leagues. As the caravel Pinta was a better sailer and had the lead, she made land and showed the signals ordered by the Admiral. The land was first seen by a sailor called Rodrigo de Triana; although the Admiral at ten o'clock at night, standing on the castle of the poop, saw a light, but so indistinct that he did not dare to affirm that it was land; yet he called the attention of Pero Gutierrez, a keeper of the king's wardroom, to it, and told him that it seemed to be a light, asking him to look, and he did so and saw it; he did the same with Rodrigo Sanchez de Segovia, whom the king and queen had sent with the fleet as supervisor and purveyor, but he, not being in a good position for seeing it, saw nothing. After the Admiral said this, it was seen once or twice, and it was like a small wax candle that was being hoisted and raised, which would seem to few to be an indication of land. The Admiral however was quite convinced of the proximity of land. In consequence of that, when they said the *Salve*, which all the sailors used to say and sing in their way, and all being present, the Admiral requested and admonished them to keep a sharp lookout at the forecastle, and to look well for land, and said that he would give to him who first saw land a silk doublet, besides the other rewards that the king and queen had promised, namely, an annual pension of ten thousand maravedis to him who should see it first. Two hours after midnight the land appeared, about two leagues off. They lowered all the sails, leaving only a storm square sail, which is the mainsail without bonnets, and lay to until Friday, when they reached a small island of the Lucayos, called *Guanahani* in the Indian language. They soon saw people naked, and the Admiral went on shore in the armed boat, also Martin Alonso Pinzon and Vin-

cente Anes, his brother, who was commander of the Niña. The Admiral took the Royal standard and the captains the two banners of the Green Cross, which the Admiral carried on all the ships as a distinguishing flag, having an F and a Y, each letter surmounted by its crown, one at one arm of the cross and the other at the other arm. As soon as they had landed they saw trees of a brilliant green, abundance of water, and fruits of various kinds. The Admiral called the two captains and the rest who had come on shore, and Rodrigo Descovedo, the notary of all the fleet, and Rodrigo Sanchez de Segovia, and he called them as witnesses to certify that he, in presence of them all, was taking, as he in fact took, possession of said island for the king and queen, his masters, making the declarations that were required, as they will be found more fully in the attestations then taken down in writing. Soon after, a large crowd of natives congregated there. What follows are the Admiral's own words in his book on the first voyage and discoveries of these Indies. "In order to win the friendship and affection of that people, and because I was convinced that their conversion to our Holy Faith would be better promoted through love than through force, I presented some of them with red caps and some strings of glass beads, which they placed around their necks, and with other trifles of insignificant worth that delighted them and by which we have got a wonderful hold on their affections. They afterwards came to the boats of the vessels, where we were, swimming, bringing us parrots, cotton thread in balls, and spears, and many other things, which they bartered for others we gave them, as glass beads and little bells. Finally, they received everything and gave whatever they had with good will. But I thought them to be a very poor people. All of them go about naked as when they came into the world, even the women, although I saw but one very young girl, all the rest being young men, none of them being over thirty years of age; their forms being very well proportioned, their bodies graceful and their features handsome; their hair is as coarse as the hair of a horse's tail and cut short; they wear their hair over their eyebrows, except a little behind, which they wear long and which they never cut; some of them paint themselves black, and they are of the color of the Canary islanders, neither black nor white, and some paint themselves white, and some red, and some with whatever they find, and some paint their faces, and some the whole body, and some their eyes only, and some their noses only. They do not carry arms and have no knowledge of them, for, when I showed them the swords, they took them by the edge, and through ignorance cut themselves. They have no iron; their spears consist of staffs without iron, some of them having a fish's tooth at the end, and others other things. As a body, they are of good size, good demeanor, and well formed. I saw some with scars on their bodies, and to my signs, asking them what these meant, they answered in the same manner, that people from the neighboring islands wanted to capture them, and they had defended themselves; and I did believe, and do believe, that they came there from the mainland to take them prisoners. They must be good servants and very intelligent, because I see that they repeat very quickly what I told them, and it is my conviction that they would easily become Christians, for they seem not to have any sect. If it please our Lord, I will take six of them from here to your

Highnesses on my departure, that they may learn to speak. I have seen here no beasts whatever, but parrots only." All these are the words of the Admiral.

Saturday, October 13.

"At dawn many of these men came down to the shore. All are, as already said, youths of good size and very handsome; their hair is not woolly, but loose and coarse like horse hair; they have broader heads and foreheads than I have ever seen in any other race of men, and the eyes very beautiful and not small. None of them are black, but of the complexion of the inhabitants of the Canaries, and it cannot be otherwise expected, for it is east and west with the island of Hierro in the Canaries in the same line. All without exception have very straight limbs, and not large but very well-formed bellies. They came to the ship in canoes, made out of trunks of trees, all in one piece, like a long boat, and wonderfully built according to the locality, and large, so that in some of them forty or forty-five men came; others were smaller, and in some but a single man came. They paddled with a peel like that of a baker, and made wonderful speed; and if it capsizes all begin to swim and set it right again, and bail out the water with calabashes which they carry. They brought balls of spun cotton, parrots, spears, and other little things which would be tedious to describe, and gave them away for anything that was given to them. I examined them closely and tried to ascertain if there was any gold, and noticed that some carried a small piece of it hanging from a little hole in their nose, and by signs I was able to understand that by going to the south or going around the island to the southward, there was a king who had large gold vessels and gold in abundance. I endeavored to persuade them to go there, and I afterwards saw that they had no wish to go. I determined to wait until to-morrow evening and then to sail for the southwest, for many of them told me by signs that there was land to the south and to the southwest and to the northwest, and that those from the northwest came frequently to fight with them, and also go to the southwest to get gold and precious stones. This island is very large and very level, and has very green trees and many streams of water, and a very large lagoon in the middle without any mountain, and all is covered with verdure most pleasing to the eye; the people are remarkably gentle, and in consequence of their desire to get some of our things, and thinking that nothing will be given to them unless they give something, and, having nothing, they take what they can and swim off to the ship; but all that they have they give for anything that is offered to them; so that they bought even pieces of crockery and pieces of broken glass, and I saw sixteen balls of cotton given for three ceotis of Portugal, which is equivalent to a blanca of Castile, and in them there must have been more than one arroba of spun cotton. I forbade this and allowed no one to take any unless I ordered it to be taken for your Highnesses, should it be found in abundance. It grows in the island, although on account of the shortness of time I could not assert it positively, and likewise the gold which they carry hanging in their noses is found here; but in order to lose no time I am now going to try if I can find the island of Cipango. At this moment it is dark and all went on shore in their canoes."

Sunday, October 14.

"At dawn I ordered the boat of the ship and the boats of the caravels to be got ready, and went along the island in a north-northeasterly direction to see the other side, which was on the other side of the east, and also to see the villages, and soon saw two or three and their inhabitants, coming to the shore, calling us and praising God; some brought us water, some eatables; others, when they saw that I did not care to go on shore, plunged into the sea swimming and came, and we understood that they asked us if we had come down from heaven; and one old man got into the boat, while others in a loud voice called both men and women, saying: Come and see the men from heaven; bring them food and drink. A crowd of men and many women came, each bringing something, giving thanks to God, throwing themselves down and lifting their hands to heaven and entreating or beseeching us to land there; but I was afraid of a reef of rocks which entirely surrounds that island, although there is within it depth enough and ample harbor for all the vessels of Christendom; but the entrance is very narrow. It is true that the interior of that belt contains some rocks, but the sea is there as still as the water in a well. And in order to see all this I moved this morning that I might give an account of everything to your Highnesses, and also to see where a fort could be built, and found a piece of land like an island, although it is not one, with six houses on it, which in two days could easily be cut off and converted into an island; such a work, however, is not necessary in my opinion, because the people are totally unacquainted with arms, as your Highnesses will see by observing the seven whom I have caused to be taken in order to carry them to Castile to be taught our language, and to return them unless your Highnesses, when they shall send orders, may take them all to Castile, or keep them in the same island as captives; for with fifty men all can be kept in subjection and made to do whatever you desire; and near by the said little island there are orchards of trees the most beautiful that I have seen, with leaves as fresh and green as those of Castile in April and May, and much water. I inspected all that harbor, and afterwards I returned to the ship and set sail, and saw so many islands that I could not decide to which one I should go first, and the men I had taken told me by signs that there were so many of them that they were innumerable, and named more than one hundred of them. In consequence, I looked for the largest one and determined to make for it, and I am so doing, and it is probably distant five leagues from this of *San Salvador*; the others, some more, some less; all are very level, without mountains, and of great fertility, and all are inhabited, and they make war upon each other, although these are very simple-hearted and very finely formed men."

Monday, October 15.

"I had been standing off and on this night, fearing to approach the shore for anchorage before morning, not knowing whether the coast would be clear of shoals, and intending to clew up at dawn. And as the island was over five leagues distant, rather seven, and the tide detained me, it was about noon when I reached the said island; and I found that that side which is towards the island

of *San Salvador* runs north and south, and is five leagues in length, and the other, which I followed, ran east and west, and contains over ten leagues. And when from this island I saw another larger one to the west, I clewed up the sails, for I had gone all that day until night, because I could not yet have reached the western extremity, to which I gave the name of the *island of Santa Maria de la Concepcion* ; and about sunset I anchored near said extremity in order to learn whether there was gold there, because the men whom I had caused to be taken from San Salvador told that they there wore very large rings of gold on their legs and arms. I well suspected that all they said was deceptive in order to get away from me. Nevertheless, it was my desire not to pass any island without taking possession of it, although, one taken possession of, the same may be said of all ; and I anchored and remained until to-day, Tuesday, when at dawn I went on shore with the boats armed, and landed, and they who were many in number, also naked, and of the same disposition as those of the other island of San Salvador, allowed us to go over the island and gave us whatever we asked for. And because the wind was increasing against the coast, southeast, I did not like to stay longer, so I returned to the ship, and a large canoe was alongside the caravel Niña, and one of the men of the island of San Salvador, who was in her, jumped overboard and escaped in it, and in the middle of the preceding night the other * and he went after the canoe, which flew so swiftly that there was never a boat that could overtake it, as it was much in advance of us. Nevertheless it reached the land, and they left the canoe, and some of my men went on shore after them, and they all ran like hens, and the canoe they had left we took on board the caravel Niña, to which from another quarter another small canoe was coming with a man who came to barter a ball of cotton, and as he refused to go on board the caravel, some sailors plunged into the sea and took him ; and I, who from the poop of my ship saw all, sent for him, and I gave him a red cap, put around his arm a string of small green glass beads, and two little bells on his ears, and ordered that his canoe, which they had also on board of the vessel, should be returned to him, and thus I sent him on shore ; and soon after I set sail for the other large island that I was descrying in the west, and I ordered that the other canoe that the Niña had astern should be turned adrift. When the man to whom I made the indicated presents and from whom I had refused the ball of cotton he offered to me, reached the land, he was as I saw immediately surrounded by those on shore, and he felt a great wonder and thought that we were good people, and that the other man who had fled had probably been kept by us in consequence of some injury done us, and that was the reason why I gave him presents and ordered his release, my aim being to win thus the esteem of all, and avoid their enmity to the future expeditions your Highnesses may send ; and yet all I gave him was not worth four maravedis. And so I left, at about ten o'clock, with a southeast wind, inclining to the south for the other island, a very large one, where the San Salvador men I have with me assert by signs there exists much gold, and that they wear it in rings around their arms and legs, and in their ears, noses, and around their necks. And from this island of Santa Maria to the other one there are nine

* Sentence illegible and unfinished in the original.

leagues east and west, and all this portion of the island runs northwest and southeast, and it appears that there may be on this side of the coast more than twenty-eight leagues; it is even and devoid of mountains, like those of San Salvador and Santa Maria, and all its shores are free from reefs except some sunken rocks near the land which require great watchfulness when one wants to anchor, or makes it prudent to anchor some distance from land, although the water is always remarkably limpid and the bottom can be seen. At the distance of two lombard shots there is in all these islands a bottom so deep that it cannot be reached. These islands are very green and fertile, and have a balmy atmosphere; they probably contain many things which I do not know of, for I do not wish to stop but to reconnoitre many islands in search of gold. And since these thus give these signs that they wear it on their arms and legs, and it is real gold, for I showed them some pieces of that which I have, I cannot fail, God helping, finding the place whence it is procured. And being in the gulf, midway between these two islands, namely, that of Santa Maria and this large one, to which I give the name of *la Fernandina*, I found a man who was going from the island of Santa Maria to la Fernandina; he had a small piece of his bread, about the size of one's fist, a calabash of water, a lump of red earth reduced to powder and afterwards kneaded, and some dry leaves, highly prized no doubt among them, for those of San Salvador offered some to me as a present; and he carried a little basket in their fashion, in which he had a small string of glass beads and two blancas, by which I knew that he came from the island of San Salvador, had passed to Santa Maria, and was now going to la Fernandina, and he came to the ship; I had him taken on board as he desired, and ordered that his canoe and all that he had should be kept in the ship; and had him treated with bread, honey, and drink: and I will take him to la Fernandina, giving him back what he has brought, in order that he may give good news concerning us, so that, God willing, when your Highnesses shall send here, those who shall come may receive honor, and that they may give us of all that they have."

Tuesday, October 16.

"About noon I left the *islands of Santa Maria de la Concepcion* for the *island of Fernandina*, which appears to be very large to the west, and I sailed all that day with calm weather; I could not arrive in time to see the bottom in order to get a clear anchorage, a thing requiring the greatest care in order not to lose the anchors; in consequence I waited until daylight, when I anchored near a village. The man whom I found yesterday in his canoe in the gulf had come to that village, and so favorable was the account he had given of us that to-night they have been constantly coming to the ship in their canoes, bringing us water and everything they have. I caused some things to be given to every one, such as small beads, ten or twelve of them of glass on a string, some brass [tin ?] rattles like those that in Castile can be had for one maravedi apiece, and some leather straps, all of which they considered of the greatest excellence, and I also treated those who came to my ship with honey of sugar [molasses ?]; and afterwards, at nine o'clock A. M., I sent the ship's boat to the shore for water, and they willingly showed my men where the water was and they themselves

brought the casks filled to the boat, and were very glad to be able to oblige us. This island is exceedingly large and I have determined to go around it, because, as I can understand, on it or near it there is a mine of gold. This island lies at a distance from that of Santa Maria of eight leagues almost east and west; and this cape to which I have come, and all this coast, runs north-northwest and south-southwest, and I saw fully twenty leagues of it, but this was not the end. Now while writing this I set sail with a south wind, intending to go around the whole island, and work until I should find *Samaot*, which is the island or city where the gold is, as all those say who have come with us in the ships, and as was before asserted by those of the island of San Salvador and Santa Maria. The people here are like those of the said islands, and speak the same language and have the same customs; but these look to me as somewhat more gentle, of better manners, and of keener intelligence, for I notice that in bartering cotton and other little things they know how to trade, which the others never did; and also on this island I saw cotton cloth made like mantles, and the people more intelligent; and the women wear in front a small piece of cotton stuff which scarcely covers what decency requires. The island is very green, level, and exceedingly fertile, and I doubt not that they sow and gather panizo, and all other things, at all seasons of the year; and I saw many trees whose shape was very different from ours, and many of them which had branches of many kinds, although growing from one trunk; and one branch is of one kind and another of another kind, and so different, that the diversity of the kinds is the greatest wonder of the world; for instance, one branch had leaves like those of cane and another like those of a mastic; and thus on a single tree there were five or six of these kinds, and all so different; nor can it be said that they have been grafted, because those trees grow wild in the field, and nobody cares for them. I know no sect among them, and as they are of very good understanding, they would in my opinion soon become Christians. The fishes here are so different from ours that it is a wonder. Some look like cocks of the finest colors in the world, blue, yellow, red, and all colors, and others variegated in a thousand fashions; their different hues being so exquisite that nobody can contemplate them without wondering, and feeling great delight in seeing them. There are also whales here; but on shore I saw no beasts whatever, save parrots and lizards; a young man told me that he had seen a large snake. No sheep nor goats nor any other beast did I see; although I have only stopped half a day, I could not fail in seeing some, should there be any. When I shall have sailed around this island I will describe its coast."

Wednesday, October 17.

"At midday I left the village where I had anchored and taken in water, in order to sail around this island of Fernandina. The wind was southwest and south; and as my wish was to follow the coast of the island where I was to the southeast, because it all runs to the north-northwest and south-southeast, and I desired to take the said route of south and southeast, because that part all these Indians whom I have on board and another from whom I received signs in this part of the south, say that on the island which they call *Samoet* [is] where the

gold is; and Martin Alonso Pinzon, captain of the caravel Pinta, into which I sent three of these Indians, came to me and said that one of them had very positively given him to understand that I should round the island much the quickest by the north-northwest. I saw that the wind was not favorable to my intended course, and was to the other; so I sailed to the north-northwest, and when I was near the end of the island, two leagues off, I found a very marvellous port with an entrance, although it may be said that there are two entrances; because it has a rocky islet in the middle, and both are very narrow; but within it there is ample room for one hundred ships, if it had sufficient depth of water, and was clear, and had also a deep entrance. I thought it worth while to examine and sound it, and so I anchored outside of it, and went in with all the boats of the ships, and saw that there was not enough depth of water. And because I thought when I saw it that it was the mouth of some river, I had the casks sent on shore for water, and on shore I found eight or ten men who soon approached us, and showed us the village near by, to which I sent my men for water, some armed, and others with the casks, and thus they got it; and because it was rather far, I was detained for the space of two hours. During this time I walked among those trees, which were the most beautiful things that were ever seen; so much verdure being visible and in as high a degree as in the month of May in Andalucia, and all these trees as different from ours as day is from night; the same was the case with the fruits, grass, stones, and all things. It is true that some trees were of the same family as others in Castile; however there was a very great difference, and the other trees of other kinds were so many that there is no person that can compare them to others in Castile. The people were all like those aforementioned; they have the same dispositions, go about naked, and are of the same size, and gave of what they had for anything that was given to them; and here I saw that some young men of the vessels obtained spears from them for some little pieces of broken crockery and glass; the men I sent for water told us that the houses which they had entered were well swept and perfectly clean, and that their beds and coverings looked like cotton nets; the houses are like military tents, very high and have good chimneys; but among the many villages which I saw none had over twelve or fifteen houses. Here they found that the married women wore cotton breeches, the young girls not, except a few who were already of the age of eighteen years. And they had there dogs, mastines and branchetes, and here they found one wearing in his nose a piece of gold the size of half a castillano, on which they saw letters; I scolded them for not having got it by giving whatever he asked, in order to see what it was, and if coin whose coin it was; but they answered that he did not dare to barter it. After getting in water, I returned to the ship and set sail, and sailed to the northwest until I discovered all that part of the island as far as the coast which runs east and west, and afterwards, these Indians again said that this island was smaller than the island of *Samoet*, and that it would be well to go back, as we would thus reach it sooner. The wind then ceased and then sprang up from west-northwest, which was contrary to our course, and so I turned around and sailed all the past night to the east-southeast, and sometimes wholly east, and sometimes to the southeast; this I did in

order to keep off the land, for the atmosphere was very misty and the weather threatening ; it [the wind] was light and did not permit me to reach the land in order to anchor. So that this night it rained very hard after midnight until almost day, and is still cloudy, threatening to rain ; and we [are] at the southeast cape of the island, where I hope to anchor until it gets clear in order to see the other islands where I have to go ; ever since I came to these Indies it has been raining much or little. I beg your Highnesses to believe, however, that this land is the richest, the mildest in temperature, and the most level and wholesome in the world."

Thursday, *October* 18.

"After it cleared up, I followed the wind, and went around the island as much as I could, and I anchored when it was no longer possible to sail ; but I did not go on shore, and at dawn I set sail."

Friday, *October* 19.

"At dawn I weighed anchor and sent the caravel Pinta to the east and southeast, and the caravel Niña to the south-southeast, and I with the ship went to the southeast, having given orders that they should keep that course until midday, and then that both should change their course and return to me ; and then before we had gone three hours we saw an island to the east, to which we directed our course, and all the three vessels reached it before midday at its northern extremity, where there is a rocky islet and a ridge of rocks outside it to the north, and another between it and the large island ; which the men of *San Salvador*, that I brought with me, called *Saometo*, to which I gave the name of *la Isabela*. The wind was north, and the said islet lay from the island of *Fernandina*, whence I had come east and west, and the coast afterwards ran from the rocky islet to the westward, and there was in it twelve leagues as far as a cape, which I called *Cape Beautiful*, which is in the west ; and so it is beautiful, round, and [the water ?] very deep and free from shoals outside of it ; at first it is rocky and low, but farther in it is a sandy beach as it is along most of the coast, and it is here that I have to-night, Friday, anchored until morning. This coast all, and the part of the island that I saw, is nearly all a beach, and the island the most beautiful thing I have seen ; if the others are very beautiful, this is still more so ; it has many trees, very green and very large ; and this land is higher than that of the other islands I have discovered, although it cannot be called mountainous ; yet gentle hills enhance with their contrasts the beauty of the plain, and there appears to be much water in the middle of the island : northeast of this cape there is an extensive promontory ; and there are many groves, very thick and very large. I wished to anchor off it in order to land and visit so handsome a spot ; but it was shallow and I could not anchor except far from land, and the wind was very favorable to come to this cape, where I have now anchored, and which I have called *Cape Beautiful*, because it is so, and, consequently, I did not anchor off that promontory, and besides, because I saw from there this cape so green and so beautiful, as are all the other things and lands of these islands, so that I do not know to which to go first, nor do my eyes grow tired with looking at such beautiful verdure, so different from our own ; and I even believe that among it there are many grasses

or herbs, and many trees which would be of great value in Spain for dyes and medicines, but I do not know them, which I greatly regret. And when I reached this cape the odor came so good and sweet from flowers or trees on the land that it was the sweetest thing in the world. To-morrow, before leaving here, I will go on shore to see what there is on this cape ; there is no population except farther inland, where, according to the information received from these men whom I have on board, their king lives and wears much gold. I intend to proceed to-morrow until I find the population, and see or converse with this king, who, according to the signs made by these men, rules all these neighboring islands, and goes clothed, and wears much gold on his person ; although I place little confidence in their assertions, both because I do not understand well and because I see that they are so poor in gold that any small quantity worn by this king would seem to them to be a great deal. I believe that this *Cape Beautiful* is a separate island from *Saometo*, and even that there is another small one between ; I do not care to examine so much in detail, because I could not do it in fifty years, because I desire to see and discover the most that I can, in order to return to your Highnesses, God willing, in April. It is true that wherever I may find gold or spices in large quantities I will stop long enough to get as much of each as possible ; I am constantly sailing in order to find some."

Saturday, October 20.

"At sunrise I weighed anchor from the place where I was with the vessel anchored at this island of *Saometo* at the southwest cape (which I named the *Cape of the Lagoon*, and I called the island *la Isabela*), in order to sail to the northeast and to the east from the southeast and south, where I understood from these men whom I have with me that the population and their king were ; and so I found the bottom so shallow that I could not enter or sail to it, and I saw that by following a southwestern route it would be a long way around, and consequently I determined to return by the course I had come from the north-northeast from the west, and to go around this island in order,* The wind, however, was so scant that I was never able to have the land along the coast except at night ; and because it is dangerous to anchor among these islands, save in the daytime (when one sees with the eye where the anchor is cast, because it is all spots, one clean, the other not), I stood off and on all this night of Sunday. The caravels anchored because they reached the land early, and thought that I would do the same at sight of their customary signals ; but I did not wish to."

Sunday, October 21.

"At ten o'clock I arrived here at this end of the rocky islet, and I anchored, as did the caravels ; and after taking my dinner I went on shore. I found there only a house, in which I found no person, and I believe that they had fled through fear, because all their household goods were there. I did not allow them to touch anything, except that I went with the captains and men to see the island. If the others appeared beautiful, green, and fertile, this one with its majestic and

* A blank in the original.

luxuriant forests surpasses them all. Here are some large lagoons, and overhanging and around them are the trees, so that it is a marvel, and here and throughout the island they are all green, and the grass is like it is in April in Andalucia ; and the songs of the little birds so that it seems as if a man could never leave here, and the flocks of parrots which darken the sun ; and birds and little birds of so many kinds and so different from ours that it is a marvel ; and then there are trees of a thousand kinds, all bearing fruit of their own kinds, and all smell so that it is a marvel, so that I feel the greatest regret in the world not to know them, because I am very certain that they are all things of value, and I bring the samples of them and also of the grasses. While going around one of these lagoons I saw a serpent, which we killed, and I bring the skin to your Highnesses. When it saw us it plunged into the lagoon, and we followed it in, because it was not very deep, until we killed it with our lances; is of seven palmos in length ; I believe that there are many like this in this lagoon. Here I found the aloe tree, and as I have been told that it is very valuable I shall to-morrow have ten quintals of it brought to the ship. While looking for good water, we went to a village, distant half a league from my anchoring place ; and the people fled at our approach, abandoning their houses, and hiding their wearing apparel and what they had in the woods ; and I did not allow them to take anything, not even the value of a pin. Afterwards some of the men came to us, and one came quite up to us : I gave him some little bells and some glass beads, which satisfied and gladdened him very much, and in order that our friendship might increase, and that he might ask something of them, I caused him to ask for some water, which they, after I had gone on board the ship, brought to the beach with their calabashes filled, and were very much pleased to give it to us. I had them presented with another small string of glass beads, and they said they would come the next day. I wanted to have all the casks in the ship supplied with water ; consequently, the weather permitting, I shall sail at once in order to go until I get an interview with this king, to see if I can get from him the gold which I hear that he wears, and afterwards to sail for another very large island, which I think must be *Cipango*, according to the signs given me by those Indians whom I have on board, and which they called *Colba*, and where they say there are large ships and many merchants, and from it to another island named Bosio, which they also say is very large, taking a passing notice of others between, and shaping my future conduct in accordance with the quantities of gold or spices that I may find. I have also decided to go to the mainland to the city of *Guisay*, present there the letters of your Highnesses to the *Grand Khan*, ask for an answer and come away with it."

Monday, October 22.

"All last night and to-day I have remained here, expecting the king or other persons to come with gold or some other valuable things. Many of these people came naked, like those of the other islands, painted some white, some red, some black, and so on in many ways. They brought spears and some balls of cotton to barter, which they exchanged here with some sailors for pieces of glass, broken cups, and pieces of earthenware. Some of these few wore pieces of gold in their noses, which they gladly gave away for a small bell such as is attached to the

leg of a hawk; but it is so little that it is nothing; it is true that for any little thing that was given them they marvelled greatly at our coming, and thought that we had come down from heaven. We took water for the vessels from a lagoon which is near to the *Cape of the rocky island*, so named by me; and in the said lagoon Martin Alonzo Pinzon, captain of the Pinta, killed another serpent like that of yesterday, of seven palmos. I caused to be taken on board all the aloes that could be found."

Tuesday, October 23.

"I should like to sail to-day for the island of *Cuba*, which, from the description about its size and riches given by these people, I infer to be Cipango. I will not stop here longer nor * around this island to go to the inhabited portion, as I had determined, in order to have an interview with this king or lord. This is in order not to stop much, because I see that there is no mine of gold here; and to go around these islands requires many different winds, and they do not blow as men would wish. And therefore the most important thing is to go where there is a great trade. I say that it is not right to stop, but to continue on one's course to examine many lands until one reaches some very profitable land, although my idea is that this is very rich in spices; but I grieve exceedingly that I have no knowledge of them, because I see a thousand kinds of trees having each one its own kind of fruit, and green now as in Spain in the month of May and June, and a thousand kinds of herbs, with flowers, of all of which none was known save this aloe of which I have had quantities brought on board the ship for your Highnesses. And I have not sailed nor do I sail for *Cuba*, because there is no wind, but a dead calm and much rain; yesterday it also rained much, yet it was not cold; on the contrary it is warm during the day, and the nights are as mild as those of Andalucia in Spain in May."

Wednesday, October 24.

"At midnight I weighed anchor from the island of *Isabela*, the *cape of the rocky islet*, which is on the northern side where I was lying, in order to go to the island of *Cuba*, which I heard from these people was very large, having much trade, and that there was in it gold and spices, and large ships and merchants; and they told me that I should go to it by the west-southwest, and so I think, because I believe that if it is such as all the Indians of these islands and those whom I have on board told me by signs, because I do not understand their language, it is the island of *Cipango*, of which marvellous things are related, and on the globes which I have seen and on the maps of the world it is in this region, and thus I sailed until day to the west-southwest, and at dawn the wind calmed and it rained, and so almost all night; and I remained with little wind until after midday and then the wind began to blow very lovely, and I carried all the sails of the ship, the mainsail, two bonnets, the foresail, and spritsail, and the mizzen, and the main-topsail, and the boat astern; thus I followed my course until nightfall, and then *Cape Verde* of the island of *Fernandina*, which is at the south towards the west, remained to the northwest of me, and there was from

* Blank space in the original.

me to it seven leagues. The wind was blowing hard, and I knew not how far off the island of *Cuba* was, and in order not to approach it at night, because all these islands are so deep that no bottom can be found all around them, save at two lombard shots, and this is all spotted—one piece of rock, another of sand—and, consequently, it is impossible to anchor safely except where you can see; and therefore I determined to lower all the sails, except the foresail, and to sail with that, and suddenly the wind grew very strong and I made much headway, of which I was doubtful, and it was very misty and rained. I had the foresail taken in and we did not go this night two leagues," etc.

Thursday, October 25.

He afterwards sailed from sunrise west-southwest until nine o'clock, making about five leagues; afterwards he changed course to the west; they went eight miles an hour until one o'clock P. M., and thence until three o'clock, and they made about forty-four miles. At that time they saw land, and there were seven or eight islands, all extending from north to south—distance from them five leagues, etc.

Friday, October 26.

He was on the southern side of said islands; all was shallow for five or six leagues; he anchored there. The Indians he had with him told him that to reach *Cuba* with their canoes from those islands would take them a day and a half; these canoes are small vessels of one piece of wood and have no sail. These are the canoes. He sailed thence for *Cuba*, because from the signs which the Indians gave him of the size and of its gold and pearls he thought that was the one, that is to say, *Cipango.*

Saturday, October 27.

At sunrise he weighed anchor from those islands which he called *Las Islas de Arena* [Sand Islands] on account of the little bottom they had for six leagues to the south. He ran south-southwest at the rate of eight miles an hour until one o'clock in the afternoon, making about forty miles, and up to nightfall they had made about twenty-eight miles on the same course, and before night they saw the land. They lay to during the night with much rain which it rained. They ran on Saturday until sunset seventeen leagues, south-southwest.

Sunday, October 28.

He went thence in search of the island of *Cuba* to the south-southwest, to the land nearest to it [him?], and entered a very beautiful river very free from danger of shoals and other inconveniences; and all the coast that he passed there was very deep and very clear as far as the land; the mouth of the river had twelve fathoms, and is very wide in order to tack in; he anchored within, he said, at the distance of a lombard shot. The Admiral says that he never saw such a beautiful thing, the banks of the river being covered with trees, which were beautiful and green and different from ours, with flowers and with their fruit, each one after its kind. Many birds, and little birds which sang very sweetly; there was a great quantity of palms different from those of

Guinea and from ours; of medium height and the feet without that shirt, and the leaves very large, with which they cover their houses; the land is very level. The Admiral jumped into the ship's boat and went on shore, and came to two houses which he thought to be those of fishermen, and which ran away in fear; they found in one of them a dog which never barked, and in both houses he found nets of palm thread and cords, and horn fish-hooks, bone harpoons, and other fishing-gear, and numerous sets within; and he believed that each house was occupied by many persons; he ordered that nothing in them should be touched, and nothing was. The grass was high as in Andalucia in April and May. He found much purslain and wild amaranth. He returned to the boat and went up the river for a good while, and he said that it was a great pleasure to see that verdure and those groves, and of the birds that he could not leave them in order to return. He says that that island is the most beautiful that eyes ever beheld, full of good ports and deep rivers, and it seemed to him that the sea must never be high there, for the grass of the beach almost reached the water, which rarely happens where the sea is rough; until then he had not experienced a rough sea in all those islands. The island, he says, is full of very beautiful mountains, though they are not very long, but lofty, and all the land is high like that of Sicily; full of many streams of water, as he could understand from the Indians with him, whom he took from the island of *Guanahani*, who tell him that there are ten large rivers, and that with their canoes they cannot go around in twenty days. While going to the land with the vessels, two canoes approached, and when they saw that the sailors entered the boat and rowed in order to go to see the bottom of the river and to know where they were to anchor, the canoes fled. The Indians said that in that island there were mines of gold and pearls, and the Admiral saw place suitable for them and shell-fish, which is a sign of them, and the Admiral understood that ships of the Grand Khan came there, and large ones, and that from there to the mainland was a run of ten days. The Admiral called that river and port *San Salvador*.

It may be of service in examining the different tracks proposed for Columbus, to have a synopsis of the information contained in the journal concerning the different islands, with their bearings and distances from each other.

San Salvador.

Large and level with large lagoon in middle. No mountains (Oct. 13).

Surrounded by reef of rocks, within which is a large harbor having a narrow entrance (Oct. 14).

Santa Maria de la Concepcion.

About SW. from San Salvador (Oct. 13). Distance from San Salvador about 5 leagues (Oct. 14), 7 leagues (Oct. 15). Side towards San Salvador extends north and south 5 leagues; the other, east and west 10 leagues (Oct. 15).

Fernandina.

In sight from Santa Maria (Oct. 15, 16). 9 leagues west of Santa Maria (Oct. 15). 8 leagues (Oct. 16).

Extends NW. and SE. more than 28 leagues (Oct. 15).

Extends NNW. and SSE. more than 20 leagues (Oct. 16). Level. A promising harbor which proved to be shallow, having a narrow entrance with rocky islet in middle on the east side (Oct. 17).

Isabela.

Not in sight from Fernandina (Oct. 19).

Rocky islet at northern extremity with ridge of rocks outside, and another between it and large island. This islet was E. from Fernandina (Oct. 19).

Coast ran to westward from rocky islet 12 leagues to Cape Beautiful (Oct. 19).

Deep water, sandy beach (Oct. 19).

Higher than other islands visited, though not mountainous. Gentle hills, apparently much water in interior. Cape Beautiful on different island from Isabela (Oct. 19).

Found shallow water in attempting to go NE. and E. from the south cape (Oct. 20).

Large lagoon near the rocky islet (Oct. 21).

Las Islas de Arena.

Chain of seven or eight islands lying north and south (Oct. 25).

Shallow for 5 or 6 leagues to southward of the islands (Oct. 26).

Reached by sailing on courses between W. and WSW. from Isabela (Oct. 24, 25).

Cuba.

Ran SSW. 68 miles* from anchorage to southward of Las Islas de Arena, and then had Cuba in sight (Oct. 27).

With these data for reference the routes proposed for Columbus through the Bahamas may be readily tested. No better criticism of

* Mr. Fox discusses the value of the league and the mile so often referred to in the journal, and reaches the following conclusions :

In several places the league is stated as four miles, as in the entry for Oct. 11. Columbus says he had made "about ninety miles, that is twenty-two and a half leagues." Again, in the run from Las Islas de Arena to Cuba, on October 27, the run is entered both in leagues and miles, 68 of the latter being equivalent to 17 leagues. The length of the mile is however somewhat doubtful. On the authority of Rear-Admiral John Rodgers and Prof. De Morgan, Mr. Fox adopts the length of 1614 yards, that of the old Roman or Italian mile, as the mile of Columbus. The league is therefore 19,368 feet or 3.18 English nautical miles. As all distances in the log are from dead reckoning, there is probably no great error committed in calling Columbus' league three nautical miles, and his mile ¾ of the present nautical mile.

these can be made than that given in Mr. Fox's Memoir. The following is in the main an abstract of his discussion. The accompanying Chart (Plate I.) is a copy of the excellent one accompanying his paper.

The first track considered is that of Navarrete from Grand Turk, which agrees in only one or two points with the journal. The distance between the second and third islands, which is given as about twenty-five miles, is here sixty, and nothing is in sight from the second. The third island, described as twenty-eight leagues in length, is here only seven. Navarrete omits entirely the fourth and fifth islands, and makes Columbus proceed directly from the third to Cuba. It is hardly possible to imagine that this track is derived from the log at all.

Varnhagen fixes on Mariguana as San Salvador. His second island bears WNW. from the first, although Columbus said he should sail SW. from San Salvador, and afterwards stated the distance between the islands as seven leagues; whereas on Varnhagen's track it is over forty miles. From the second island, Varnhagen's track coincides in the main with others to be discussed, and need not be considered separately.

Washington Irving makes Cat Island to be Guanahani, and his theory, given as it is in full in his life of Columbus, has become widely known and has obtained considerable support. Although as far as Cat Island itself is considered there is no discrepancy with the bits of description given of San Salvador, there are difficulties met with that seem insuperable in following Columbus therefrom. Irving's second island (Conception Cay) is SSE. from Cat Island, although, as already stated, Columbus said he should sail SW. The third island in this track is Exuma, and the fourth, Long. In order to reach Exuma, the ships would have had to pass close to Long Island, and could not have avoided seeing it. The log states that on leaving the second island the ships went to the land in sight, but Irving makes them pass it and push on towards Exuma, which is not visible even from Long Island. On the 19th the ships steered on different courses to pick up the land, showing conclusively that Columbus knew of its position only by hearsay; yet, according to the track assigned him by Irving, he had passed only four days before within a mile or two of the very island he was then seeking. From Long Island, Irving supposes the ships to have proceeded SW. to Mucarras Cay and Cuba. A glance at the chart shows this to be the fatal objection to this route, as it passes the Jumentos Cays, and thence over the Great Bahama Bank, a region

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PLATE I

CHART OF PART

OF THE

BAHAMA ISLANDS

SHOWING THE TRACKS ASCRIBED TO

COLUMBUS

ON HIS DISCOVERY

OF THE

NEW WORLD

NOTE

SOUNDINGS IN FATHOMS

(From the U.S. Coast and Geodetic Survey Report 1880)

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which is to-day almost wholly unnavigable. No mention is made in the log of any shoal water on this passage, although as soon as it is encountered south of Las Islas de Arena it is recorded. The distance is also widely different, being 120 miles, whereas the log accounts for not more than 80. The Mucarras Cays do not correspond with Las Islas de Arena in number and position, and are only 26 miles from the Cuban coast, whereas the log says that the ships sailed 54 miles and then had Cuba in sight only.

Captain Becher, R. N., published a book entitled "The Landfall of Columbus," in which he adopted Watling's Island as Guanahani; his decision has probably been more widely received than any other. But Mr. Fox shows conclusively that the assumed track from San Salvador to Cuba is widely at variance with the log, and is only an ingenious attempt to reconcile facts with a preconceived theory. The first point of difference is in the log of the 15th. The Spanish reads: "y como desta isla vide otra mayor al Oueste, cargué las velas por andar todo aquel dia fasta la noche, porque aun no pudiera haber andado al cabo del Oueste. . . . y cuasi al poner del sol sorgí acerca del dicho cabo." Captain Becher translates: "And as from this island I saw another larger one to the westward *I made sail*, continuing on until night, for as yet I had not arrived at the western cape." Professor Montaldo's translation is, "And when from this island I saw another larger one to the west *I clewed up* the sails, for I had gone all that day until night, because I could not yet have reached the western extremity." The vital difference is in the translation of "cargué las velas." The verb "cargar" means ordinarily to press or to crowd, and its translation by Becher "I made sail" is therefore natural; but "cargar las velas" is a technical term, meaning to clew or brail up the sails, a signification the reverse of what it ordinarily has. Mr. Fox, who had a translation by Professor Montaldo, adopts his interpretation of this passage, although giving some one else as the authority. The question once raised, any dictionary of nautical terms shows that the true rendering of "cargué las velas" is "I clewed up the sails." Becher's erroneous translation leads him into the hypothesis that Columbus did not stop at the second island that he reached, but pushed on towards the one in the west. Even if this hypothesis were correct, it affords no justification for the tampering with the name given by Columbus to the second island, Santa Maria de la Concepcion. Becher supposes that he passed Rum Cay without stopping and pushed on to

Long Island, where he anchored about sunset; but he divides the above name, giving to Rum Cay the first half of it, Santa Maria, and to Long Island the remainder, Concepcion. This division would seem to be almost too absurd for credence, yet it has actually been adopted by the British Admiralty. It is charitable to suppose that they are aware that they are accepting names due only to the fertile imagination of Captain Becher, and not those given by Columbus. The evidence is conclusive in the log that Columbus did *not* push on to the land he saw to the westward; for in two places in the log of the 15th, and in one of that of the 16th, reference is made to the land visible to the westward. It was in sight, but not until noon of the 16th did the ships leave the second island to sail to it. It cannot be urged in defence of Captain Becher that the ships anchored at sunset of the 15th at the north end of Long Island and sailed thence on the 16th for his next island, Exuma; for, Exuma is not in sight from Long Island. Becher slights the "marvellous harbor" described in the journal of the 17th, saying that it is "really nothing more than the low shelving shore of the island (Exuma) covered to the depth of a few feet by the sea." The real difficulty is that there are two excellent harbors in Exuma which do not at all agree with the one described by Columbus, which appeared to be a good port, but which proved to be shallow.

But Captain Becher's fancy takes its highest flight in the course he attributes to Columbus on the night of the 17th. He fixes on the Crooked Island group as the Samoet or Isabela of the journal, and it is necessary to get the ships there, although at sunset they were a hundred miles distant, at Great Exuma. He therefore writes of the heavy gale on that night from the westward, before which Columbus ran ESE. until he cleared the north end of Long Island, when he hauled to the southward, skirting the shore and anchoring at daybreak at the south end of Long Island, which he supposed to be the south end of Exuma. The distance is about one hundred miles, the time allotted, about ten hours. There are several objections to this assumed run. First, no seaman of Columbus' ability would run all night at such a speed in an absolutely unknown sea; second, *there was no gale!* The log is explicit: "the wind was light, and did not permit me to reach the land to anchor." Mr. Fox says of Becher's hypothesis, "He 'bounds him along' the reef of this coral island and into the unknown darkness as if it was as easy to do so as to write about it. He makes him straddle a strange island during a stormy night and witlessly anchors him at the end of the wrong one in the morning."

For the fourth island (Isabela), Becher fixes on the Crooked Island group, and no one can read the journal with chart in hand (see Plate III.) without noting how closely the topography agrees with the text. In the run from Isabela to Cuba, Becher allows one and a half points westerly variation in order to bring the ships into the port of Nipe; but, as will be shown later, the reckoning of this run is too uncertain to admit of any positive conclusions based on it alone. Appended to Mr. Fox's monograph is, moreover, a discussion of the variation of the compass in the Bahamas in 1492, by Mr. Schott, Assistant, U. S. Coast and Geodetic Survey, in which the conclusion is reached that the variation was not more than a quarter of a point west.

Thus far we have followed Mr. Fox's criticism only; but his own route is also open to objection, and must next be considered. It is apparently founded on the description of the second island.

The log says (Oct. 15) that "the side which is towards the island of San Salvador runs north and south and is five leagues in length; and the other which I followed ran east and west and contains over ten leagues." Captain Fox says: "Crooked has a north and south side 13 miles, and another which runs west by north and east by south 29 miles. I wish the reader to take heed that it is the second island and no other of which the journal records the length and trend of two separate sides; and that Crooked is the only one in the Bahamas which conforms to this description."

This coincidence is certainly a remarkable one, and if a theory founded on it did not conflict in any point with the journal it would be almost conclusive. The description of San Salvador is too meagre to enable any one to urge final objections against Mr. Fox's choice of Samana, but the description does not agree so closely with it as with Becher's choice of Watling. The objections to his route rest not on the first island but on those visited later. From the second island Columbus saw "another larger one to the west," but Long Island, Mr. Fox's third island, is invisible from his second. He admits this; in fact, he particularly investigated the point, and explains the inconsistency by two suppositions: one, that extensive physical changes may have been in progress in the Bahamas since 1492; the other, founded on the statement of the light-house keepers at Bird Rock, off the NW. point of Crooked Island, that, although Long Island is not visible itself, yet clouds sometimes settle over it in clear weather like a stretch of land. It is possible that changes have taken place, but it may be questioned whether any extensive settling of the land

has occurred since 1492. Long Island would necessarily have been at least two hundred feet higher than it now is to have shown from Crooked Island. An objection is found, in the positiveness of the statements of the journal on two different occasions, to the second supposition, that Columbus mistook clouds for land. These entries were both apparently made before the third island was reached, when the only evidence of its existence was the fact that it was in sight. Columbus was too experienced a seaman to be so completely deceived by an appearance of land as to make positive entries in the log that it was in sight, if there was nothing but a bank of clouds.

Difficulty exists in reconciling Mr. Fox's track with the entry under date of October 15, when speaking of the third island, "it appears that there may be on this side of the coast more than twenty-eight leagues"; this entry is modified, but confirmed in an entry of the following day, that "I saw fully twenty leagues of it, but this was not the end." The description of Fernandina agrees very closely with the topography of Long Island; but if Columbus approached the southern end from the eastward, how did he know of the length of the island, and how did he *see* twenty leagues *before* he commenced his trip along the coast? Five or six leagues would probably be about all that would be visible on such a line of approach.

There can be but little doubt that the southern end of Long Island was the point from which the ships of Columbus set sail on the morning of October 19. Becher, Fox, and Varnhagen, although differing widely in their tracks up to this point, all agree here. Mr. Fox is, however, unable to agree with the others on the fourth island, as they assign one that he has already chosen as his second. He is therefore compelled to adopt views that seem to be unnatural and utterly untenable. On getting under way on the 19th for Samoet, concerning which he had heard so much from the natives, Columbus deployed his ships on different courses, evidently with the intention of picking up land as soon as possible. This line of action is proof that he was ignorant of the exact situation of Samoet, and was fearful that he might miss it if he kept his vessels together. The courses steered varied between ESE. and SSE., and it is impossible to imagine that any such proceeding would have been adopted if he had already come from an island in almost the exact direction towards which he was now steering. Mr. Fox makes Columbus sail about W. by N. on the afternoon of the 16th, from the second island to the third, and then on the 19th has him groping his way blindly ESE., SE.,

and SSE., in search of land, which he knew was in that direction. The journal states further that he reached the land about midday "at its northern extremity, where there is a rocky islet and a ridge of rocks outside of it to the north, and another between it and the large island." No description written to-day could more clearly describe Bird Rock off the NW. point of Crooked Island (Plate III.); but this point chosen by Becher and Varnhagen is denied Fox, as it is the position he assigns for the anchorage of the night of the 15th; and although he cites an instance in which Columbus sailed past a portion of the coast of Hayti without recognizing it, he cannot claim that he was so thoroughly deprived of all seamanlike instincts as not to recognize the same anchorage he had left only three days before. That the large island was a new one is evident from the fact that Columbus gave it a new name, that of Isabela, and furthermore described it as the most beautiful he had seen. "This land is higher than that of the other islands I have discovered; although it cannot be called mountainous, yet gentle hills enhance with their contrast the beauty of the plain; and there appears to be much water in the middle of the island."

Crooked Island, with hills 200 feet in height, is higher than any of the other islands in the vicinity, and agrees in almost every particular with the bits of description scattered through the next five days of the log. The note that the "rocky islet" bore east from Fernandina is in exact accordance with the bearing of Bird Rock. There would seem to be no manner of doubt that a person free to apply the description to any island fulfilling it would select Crooked Island.

Mr. Fox's dilemma is, as has already been stated: Crooked is his second island. He has therefore to choose another, and he has taken Hobson's choice, Fortune Island being the only one available. But Fortune, far from being the largest and most hilly of the islands visited, is smaller and more nearly level than Crooked Island, which is separated from it only by a narrow creek, now almost dry at low water. Would any seaman use the language of the log,—that he reached the land "about midday at its northern extremity, where there is a rocky islet and a ridge of rocks outside it to the north, and another between it and the large island,"—if he had run into a bay between two islands? The description manifestly places the large island to the southward of the islet; but if for the rocky islet of the log we accept one of the low islands lying in the bayou between Crooked and Fortune, the large and hilly island is to the *northward* of the

islet. Is it reasonable to suppose that a discoverer would find himself in a position like this without making mention of the land on each side of him, especially if by anchoring off the passage between them he saw that they were separate islands? Would he speak of a rocky islet as off the north end of a large island when it was to the southward of the larger of the two? Between the 19th and 24th Columbus made several attempts to circumnavigate the islands, but was unsuccessful. In all this time not a single expression used in the log gives any idea that he recognized the land to the northward (Crooked Island) which Mr. Fox has had him visit on the 16th. He repeatedly communicated with the shore, and as it was his custom to give presents, and in every way to seek the confidence of the natives of the islands he visited, he would have ascertained the fact of his previous visit (if such there had been) from them. He had with him a number of natives from San Salvador, who recognized the large island and gave it the name of Saometo. In the journal of the 16th, Columbus said that he should work until he found this island, as he had learned from the inhabitants of Santa Maria that it contained gold. On Mr. Fox's track, Santa Maria and Saometo are not only in sight of each other, but separated by a mere bayou less than a mile wide! Mr. Fox bases his whole track on the correspondence between the account given in the journal of the second island and the northern and eastern sides of the Crooked Island group, thereby denying himself the privilege of observing how equally exact is the correspondence between the description of the fourth island, which is given in greater detail, and that of the western side of the same group. He is in fact compelled to adopt Fortune, and says: "The journal is obscure in regard to the fourth island. The best way to find it is to plot the courses forward from the third island, and the courses and distances backward from the fifth. These lead to Fortune for the fourth." In reply to this, if one will read the journal with the idea in mind that Crooked and Fortune together form the fourth island, he will find no obscurity. Columbus even ventures the statement that he thinks there are two islands, and that a small one lies between, but says he had not time to decide a question of so little importance. There is no course given from the third to the fourth, so that that cannot be plotted; but a bearing is given of the "rocky islet" as east, the exact bearing of Bird Rock from the south end of Long Island, a bearing which Mr. Fox says might easily be $1\frac{3}{4}$ points in error. So

it might be, but in following his own directions for finding the fourth island by plotting from the third, we are led to believe that its position is as exact as an experienced navigator could determine it.

It is well in this connection to make another quotation from Mr. Fox. "The strain of a seafaring life from so tender an age is not conducive to literary exactness. Still, for the very reason of this sea experience, the 'log' should be correct. This is composed of courses steered, distances sailed over, bearings of islands from one another, trend of shores, etc. The recording of these is the daily business of seamen, and here the entries were by Columbus himself, chiefly to enable him on his return to Spain to construct that nautical map which is promised in the prologue of the first voyage."

It is impossible to follow Mr. Fox's suggestion, to plot the courses and distances backward from the fifth island, with sufficient exactness to determine between Crooked and Fortune Islands. The general statement is made that the course was WSW. from the "rocky islet"; but as distances are all measured from an observed departure, we know nothing of the distance that had been sailed when the departure was taken. This departure is the bearing of the southwest cape of Fernandina (which can be accepted with almost absolute certainty as Long Island) as NW. seven leagues. The distance is probably overestimated, as but little land in the Bahamas is visible with sufficient distinctness to answer as a point of departure at that distance; but the bearing alone is of the greatest importance.

After the departure had been taken, a gale arose during the night (October 24), and after taking in everything but the foresail, Columbus was finally compelled to take that in also. Dead reckoning in such a run cannot be relied upon with great certainty. Mr. Fox, in his anxiety to prove that Fortune is the fourth island, makes an error in working back from the fifth, in putting all the run between the departure and the time of anchorage off the Sand Islands as made on one course. The log gives WSW., five leagues (16 miles), two leagues drift (direction not stated), and west, 44 (35 nautical) miles. At that time a chain of islands running north and south, distant five leagues, was sighted, bearing not given. On the next morning, Columbus anchored to the southward of these islands, course and distance in the interval not stated. Mr. Fox calculates all the above as WSW., but the reckoning worked up places Columbus, at the time he sighted land, in latitude 22° 29′, longitude 75° 31′, almost NNE. of the position where Mr. Fox has him anchored on the 26th. The data

given for this run are too incomplete for any accurate calculations, and cannot justly be used to identify Fortune as the fourth island.

Apparently none of the tracks thus far proposed from San Salvador to Cuba fulfil the requirements of the journal of Columbus. Common fairness requires, however, that a criticism should not only point out wherein a treatment of a subject is defective, but that it should also substitute something presumably better. In studying the tracks detailed above, certain conclusions seemed to present themselves naturally, and although many of them have been suggested by others, some will be found to be new; the combination is different from any yet proposed. I have been led to the following interpretation of the log of Columbus:

It is certain that Columbus reached the north coast of Cuba, although there may be some question as to the exact point; but as his courses and distances are given in this part of the voyage with considerable exactness, we can begin to follow him backwards with the advantage of having a known point to start from, and we can thus trace him back to his landfall. He left the Sand Islands at sunrise of the 27th, and by nightfall saw the land, having then run about seventeen leagues SSW. In making this run, he was crossing a strong current that sets to the WNW. along the north coast of Cuba; allowing an average strength of two miles an hour, which is in excess, if in error, the bearing of his morning anchorage would have been NE., and the distance 58 miles, at sunset. At this time, however, the coast of Cuba was in sight, distant not more than twenty miles. We are therefore justified in saying that the anchorage from which he sailed to Cuba was about 75 miles northeast of the latter. This anchorage is described as being on the south side of Las Islas de Arena, "seven or eight islands, all extending from north to south," and it is also mentioned that "all was shallow for five or six leagues on the southern side of said islands." Taking a chart of the region, if we lay off 75 miles of the scale with a pair of dividers, and sweep along the chart, keeping one point of the dividers on the Cuban coast and the other on a northeast bearing, the latter should pass near the morning anchorage. The only land it approaches is the Ragged Island chain, and the coincidence between these and the descriptions given above is so exact that there seems to be hardly an opportunity for mistake in designating them as Las Islas de Arena. The distance of an anchorage south of these islands from the nearest point of Cuba is

about 70 miles, and as no other islands at all answer to the description, we can almost positively fix the position of Columbus on the morning of the 27th as at anchor to the southward of the Ragged Islands.

The reckoning of the passage from Isabela to Las Islas de Arena is not given in full, but the general course is stated to have been about WSW., and the approximate distance between the position of the departure from Cape Verde and the point from which Las Islas de Arena were sighted is, as calculated from the courses and distances given in the log, fifty miles, and the course made good, W½S. The distance of the islands when first seen is given as five leagues, and we have to conclude therefore that the position at sunset on the 24th was about 65 miles, E½N., from the Ragged Islands. Laying off this distance and bearing from the two extreme islands of the chain, and connecting the points thus determined, we have a line of bearing (Plate I.) that should contain the position of Columbus at the time he took his departure. But this position was SE. from Cape Verde, the south point of Fernandina, and WSW. from the "rocky islet" at the northern extremity of Isabela. These bearings immediately point to Long Island as Fernandina, and to Bird Rock as the "rocky islet." The exact manner in which Crooked and Fortune islands taken together fulfil the descriptions of the journal from the 19th to the 24th, has already been pointed out, and we are led, therefore, to identify Crooked and Fortune as the Isabela of Columbus, and the Saometo of the natives.

Isabela, or rather the "rocky islet," at its northern extremity bore about east from Fernandina, the only idea of the distance derivable being that the ships were about six hours crossing from one island to the other. Long Island, already indicated as Fernandina, from the departure taken from its southern cape, lies 25 miles west of Bird Rock (identified as the rocky islet), and corresponds very closely to the description of Fernandina as an island over twenty leagues long, extending NNW. and SSE.

We now reach the debatable point of the discussion. There can be but little doubt that thus far we have identified the islands visited; but the second island, Santa Maria, offers more difficulties. Captain Becher is compelled to alter the journal in order to adapt it to the topography, and Mr. Fox, by making the second island the keystone of his argument, is obliged to bring Columbus back almost on his own track. It is to be noticed that both Isabela and Santa Maria lay eight or

nine leagues east of Fernandina. It may also be inferred that they were distant from each other, or Columbus would have known of the position of Isabela, which he describes as the highest island he had up to that time visited, having seen it from Santa Maria. The uncertainty with which he writes of the position of Samoet or Isabela on the 17th, after he had been to Santa Maria, shows conclusively that it was not visible, and that the two islands must therefore be more than twenty miles apart. This inference seems to be almost indisputable, and, if correct, a glance at the chart shows that there is only one island on which we can fix as the Santa Maria de la Concepcion of Columbus, namely, Rum Cay. How does it fulfil the other conditions? The objection immediately presents itself that, instead of being eight or nine leagues from Fernandina, it is only fifteen miles, and this would be serious if in this particular point the journal did not appear to contradict itself. Columbus states emphatically on two occasions, that from Santa Maria he saw Fernandina, "appearing very large in the west"; but his estimate of the distance must have been defective, as there is no land in this part of the Bahamas that would be visible twenty-five miles from the deck of a small vessel. The fact of visibility cannot be reconciled with the distance given. Neither Washington Irving, Capt. Becher, nor Mr. Fox selects an island as Santa Maria from which the next island can be seen; and as Rum Cay meets this requirement, and as we have been led to select it by an independent course of reasoning, the objection of the wrong distance between the islands may be counterbalanced by the fact that in this case only is the third island visible from the second. Another objection to Rum Cay is that it does not agree with the description of the second island, as having a shore east and west, ten leagues in extent, and another, next to San Salvador, five leagues north and south. The north shore of Rum Cay is ten *miles* east and west, and its east side, which lies towards San Salvador, is five *miles* north and south. Capt. Becher pays but little attention to the size of the various islands as described, and Mr. Fox is compelled in two places to suggest that *leagues* in the journal should read *miles*. Without claiming this to be the case, it is possible; and the fact that the trend of the shores of Rum Cay is in conformity with that of Santa Maria is noticeable.

Lastly, San Salvador is seven leagues, or about twenty-two miles, from Santa Maria, presumably northeast. On the valuable chart accompanying Mr. Fox's monograph, the SW. point of Watling's

Island is nineteen miles from the nearest part of Rum Cay, and bears NE¼N. We are thus led to fix on Watling's Island as the Guanahani of 1492. In choosing it, no evidence has been considered other than that of Columbus himself, and it has been identified by his directions rather than by trying to lead him into conformity with a preconceived theory. It only remains to follow him through the details of his cruise, and to examine whether the course already traced enables us understandingly and naturally to interpret his logbook.

Mr. Fox gives excellent authority, that of Prof. Harkness of the Naval Observatory, for the statement that at the time San Salvador was sighted the moon was three hours high and favorably situated for seeing land to the westward. The vessels hove to and anchored off Guanahani the next morning. It is difficult to determine where Columbus anchored, as the journal contains no positive statements. The verbatim copy does not begin until after Guanahani had been reached, and Las Casas, in copying it, neglected to state anything on a point so unimportant to him as the anchorage. On the 13th the journal says, that "by going around the island to the southward" land could be reached; on the 14th Columbus took all the boats of the fleet and went NNE. to "see the other side, which was on the other side of the east (point ?)." These two expressions would seem to indicate an anchorage on the northwest side of the island. The speed of the ships during the night, nine knots an hour, indicates that they had not only a fresh breeze but also a fair one, and in that case the east side of the island would have been the weather side. It is therefore most probable that the anchorage was on the west or lee side of the island.

The choice of Watling's Island as Guanahani is not new, it having been designated by Muñoz as long ago as 1793 as Columbus' landfall, and it has for many years been widely accepted as such. There is nothing in the description of San Salvador that conflicts in any way with the topography of Watling's Island, but, on the contrary, there is so strong a correspondence as to have led to its having been designated long before any attempt was made to identify the other islands. It agrees with the short bits of description given by Columbus, in having a large lagoon in the middle, and a rocky reef surrounding the island. It is questionable if a coral reef existing in 1492 would now be entire, and as these reefs are found more or less throughout the Bahamas, neither the presence nor absence of one would be a strong argument either way. There is to-day a reef

harbor at the northern end which would answer the description in many respects, although it is too shallow for large vessels.

Some time in the afternoon of the 14th the ships of Columbus left San Salvador, presumably steering southwest, as he said he should do, in search of gold and precious stones. From its very beginning, the career of Spanish discovery and conquest in the New World was guided by the thirst for wealth, and Columbus shows in his journal, day after day, how he was led from island to island by the vague and oftentimes misunderstood signs of the Indians, that farther on gold was plentiful; and although repeatedly disappointed, he was then and again led to put faith in these golden rumors.

On leaving San Salvador, the distance to the next island, given as five and afterwards as seven leagues, would seem to be but a short passage, but as it was dark before the island was reached, the ships lay off and on during the night, and apparently drifted so far away that they did not arrive before noon of the 15th. Mention is made of detention due to the tide, but nothing is said of which way the ships were set. The sailing directions make but little mention of any tidal current on the outer edge of the Bahamas; but the currents are very strong. The sailing directions issued by the U. S. Hydrographic Office, 1877, say that "almost everywhere through these islands the current sets to the westward at the rate of half a mile to a mile an hour." In the vicinity of Rum Cay they are either to the NW. or to the SE. In the track drawn on the chart (Plate I.) it is assumed that the current causing the detention was setting to the SE., but it is impossible to decide from the context which way the ships were drifted, and it is not intended, in assigning this drift to the SE., to assert that one in the opposite direction is not possible. It is also doubtful whether Columbus followed the north or south shore of the island to its western cape. These details are of little importance and cannot be exactly determined. At sunset on the 15th the ships "anchored near the west cape." The best anchorage at Rum Cay is on the south side of the island, near the eastern extremity, but there is an open roadstead under the west end that affords excellent shelter in any easterly wind. This was probably the anchorage of Columbus.

At dawn of the 16th Columbus went ashore in the boats, but, to use his own words, did not wish to stay, "porque el viento cargaba á la traviesa Sueste." This passage has been variously rendered, but usually in some way different from its ordinary signification. The word "traviesa" is the modern "travesia," and is used in nautical

parlance in speaking of the wind when it blows directly on a coast or directly into a port or harbor. The phrase, as used here, may possibly have reference to the fact that, if the wind increased, Columbus might find difficulty in reaching the ships with his boats, as he was anxious to be back and to get under weigh. Another explanation, which is afforded by the track proposed in this paper, is that he wished to get to the southward, and wished to start before the wind came more nearly ahead. It is to be noticed that two different times are assigned in the log for the departure from Santa Maria. In the journal of the 15th is a note, evidently written on the next day, saying, "and so I left about ten o'clock"; under date of the 16th the time of departure is given as noon.

It has always been assumed that on leaving Santa Maria the course to the next island was west. There is no course given anywhere in the journal, although the bearing of the two islands is twice mentioned as east and west; but there are the best of reasons for thinking that the course sailed was not west, but as nearly south as the wind would permit. The third island bore west from the second, but after reaching it Columbus says it extended NNE. and SSW., and that he "saw more than twenty leagues of it, but this was not the end." From the deck of his vessel, or even from the mastheads, he could never have seen more than six or seven leagues of the shore, if steering west; and the fact that he twice records its length, once under the date of the 15th as twenty-eight leagues, and again on the 16th as more than twenty, admits of but one explanation, that he sailed *along* the coast of the island in sight of it. It is by no means certain that the phrase "inclining to the south" (on the 15th, when he says, "and so I left at about ten o'clock with a southeast wind, inclining to the south") does not refer to the course steered, and not, as it first appears, to the direction of the wind. But there are still other inferences to be drawn in favor of the idea that he went to the southward. One is that on the 17th Columbus evinces a desire to sail to the southeast, as he understood from the Indians whom he had brought with him, that in that direction lay the island of Samoet, where gold was to be found. But these Indians were with him on the 16th at Santa Maria, and in addition to their information he had that of the inhabitants of the island as to the position of Samoet. He twice expresses his wish to reach Samoet, and it is therefore reasonable to suppose that on leaving Santa Maria he had that island and not Fernandina as his objective point, although he went to the

latter in accordance with his general principle not to pass any island without visiting it. If he did stand to the southward on leaving Santa Maria, it is easy to account for what has already been referred to as an erroneous estimate of the distance between the second and third islands east and west, for Columbus did not pass over the intervening distance, but estimated it from his anchorage. Experienced seamen differ widely in their estimates of the distance of land when they have nothing but their judgment to rely upon.

These reasons seem sufficient to justify the track laid down on the chart. The interpretation given the log is, therefore, that the vessels got under way between ten o'clock and noon from their anchorage at the west end of Rum Cay, and stood to the southward, or as nearly so as the wind would permit, "inclining to the south." During the afternoon the wind was light, and as they could not reach land to pick out an anchorage by daylight, they stood off and on during the night, working to the southward. At daylight of the 17th Columbus came to anchor near a village. He says, "this cape to which I have come, and all this coast runs NNW. and SSE.,"* indicating that the cape was not a prominent one. He also says that he saw twenty leagues of the island, but that "this was not the end." Reference is also made to information derived from natives "in this part of the south." The position of the anchorage is, on this authority, located on the eastern shore of Long Island, near its southern extremity. The chart shows a hill near a bend in the coast-line, which might be called a cape, and this agrees well with the description given. The distance from Rum Cay to this point is about forty miles, and the time the vessels were under way from noon to daylight the next morning seems ample for them to have made the trip, even if the wind was light during the night.

At noon of the 17th the ships were again under way. The wind was from south to southwest. Here Columbus manifested a strong desire to go to the south and southeast in search of Samoet, but, on the advice of Pinzon, who understood from the natives that the island could be rounded best by steering to the northward, consented to skirt the coast to the NNW. When he was two leagues from the end or cape † of the island he discovered what he calls a marvellous harbor with two mouths, so attractive that he came to anchor and

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C St. Maria
RUM CAY
Salt Pond
Port Nelson
Flood Stream sets along shore to the Westward
LONG
ISLAND
Little Turtle
Turtle Rk.
Deadman Cay
W. Corner Rk.
Corner Rk.
Long Rocks
Strachan Cay Beacon
Salt Pond
Salina
Probable Anch. Oct. 17th A.M.
Probable Anch. Oct. 16
C. Verde (of Columbus)
South Pt.
White Cliffs 50 ft.
75°
23°
PLATE II
LONG ISLAND
AND
RUM CAY.
SURVEYED BY COMMANDERS R. OWEN,
E. BARNETT AND T. SMITH, R.N.
1836 to 1848
CORRECTED TO 1872
Soundings in Fathoms _ Heights in Feet
From U.S. Hydrographic Office Charts

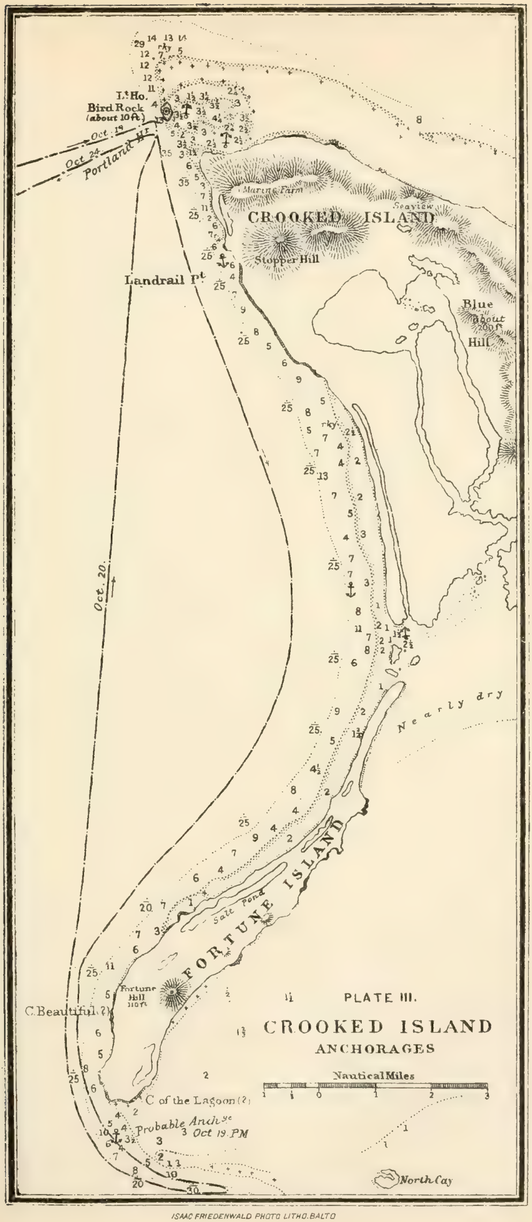
went in with the boats to examine it, but found it too shallow for the ships. This harbor, far from being of assistance in tracing his route, has offered many difficulties. Becher dismisses it with scarcely a notice; Washington Irving identifies it as Exuma Harbor, but in doing so cannot reconcile the succeeding portions of the log with the topography. Mr. Fox fixes on Clarence Harbor, on the east side of Long Island, which agrees admirably with the description. The only difficulty is in reconciling its position with the distance given, two *leagues* from the cape or end of the island; and he explains it by supposing it to be two *miles* from the cape formed by the northernmost of the row of islets on the east of the harbor. Another and apparently a better explanation is that Columbus, instead of using "cabo" in its general acceptation of "end," referred to the "cape" where he had anchored in the morning, which he also calls "cabo," although the context shows that it was not at the end, but rather in the middle of the coast-line. If this were so, his meaning would be, "After I had gone two leagues, or was two leagues from the cape where I anchored, I found a marvellous harbor." After sounding the harbor, he filled the water casks, losing two hours, and then returned to the ships and set sail. The afternoon must then have been far gone, and on reaching that part of the coast which runs east and west and which is only two miles farther, he was becalmed. The wind coming out from the WNW., he turned and headed to the southward and eastward as he had originally wished to do. It is evident, when we consider the time spent at the harbor, and the fact that he experienced a calm shortly after leaving it, that he had not made great progress during the whole afternoon; and if we accept the explanation given above, that he sailed two leagues and found the harbor, the whole run would not have been more than eight or nine miles. After turning, Columbus ran to the southward and eastward in thick, threatening weather, but with so little wind that he could not get near the shore for an anchorage. It rained heavily during the latter part of the night, and the next day, probably in the morning, he ran round the southern end of the island and anchored. This is the night in which Columbus, according to Capt. Becher, might have been taken for the Flying Dutchman, running along an unknown coast, ten knots an hour, with no wind.

On the 19th the desire of Columbus to go to the southward and eastward was gratified, the three ships getting under way at dawn and starting on different courses so as to avoid all chance of passing

Samoet without seeing it. As soon as land was sighted, all headed for it. There could be no better evidence than this that Columbus was in an unknown sea. He had heard of the existence of land in that direction and he took every precaution to sight it; whereas Mr. Fox and Varnhagen make him come *from* this same land on his way to Fernandina. The ships made the land at a rocky islet at the northern extremity, described so accurately as to leave no doubt that the Bird Rock of to-day is the land indicated. The agreement of Crooked Island with Isabela has already been pointed out, and they differ in only one respect; the distance of Cape Beautiful* from the rocky islet is stated as twelve leagues; but, assuming Cape Beautiful to be the present Fortune Hill, the distance is in reality only twenty miles. Another cape, the Cape of the Lagoon, described as the southwest point of the island, is mentioned; this is now only about two miles from Fortune Hill. It is hardly probable, however, that the Fortune Island of to-day is of exactly the same size as in 1492, as a long, narrow spit, like the one of the present maps, is subject to great erosion at its end; consequently, the old island may have been much longer. A most exact coincidence is found in the remark of Columbus, that he believed "this Cape Beautiful is a separate island from Saometo, and even that there is another small one between," a belief that the chart shows to be correct.

At sunrise on the 20th the ships were under way. The first attempt seems to have been to pass directly east from the anchorage at the southern end of Fortune Island, but this was prevented by shoal water. Coasting along the shoal to the southwest, and rounding the island in that direction, was thought of, but was abandoned as taking too

* An inconsistency exists in the log of the 19th. The rocky islet is stated to be east of Fernandina, and Cape Beautiful is twelve leagues (38 miles) west of the islet. This would place Cape Beautiful very near Fernandina, if not to the westward of it. Assuming the bearing and distance to be correct, and that Cape Beautiful, from being so far to the westward, was the first land (distant not less than ten miles) sighted by Columbus when coming from Fernandina, the vessels must have made forty-eight miles in the three hours which elapsed between sighting land and reaching the rocky islet. This absurdity arises from the bearing of the cape as west of the islet, but the bearing seems to conflict with an entry in the log of the 20th. Columbus says: "I determined to return by the course I had come from the NNE.," a statement which indicates that Cape Beautiful was SSW. of the rocky islet. This position not only avoids the discrepancy pointed out, but also agrees closely with the topography of Crooked and Fortune islands.



ISAAC FRIEDENWALD PHOTO LITHO. BALTO

much time, and the vessels therefore returned to the rocky islet, where they lay at anchor from the 21st to the 24th. Vain attempts were made to communicate with the king of the island in hopes of obtaining gold; but after repeated disappointments Columbus abandoned the scheme and looked forward to arriving at Cuba, which he believed to be Cipango from the accounts he received of its riches and the number of merchants there. At midnight of the 23d–24th the ships left the anchorage off the Rocky Islet, following the WSW. course which the natives had given. The dead reckoning, from the departure on the 24th to 3 P. M. on the 25th, when Las Islas de Arena were sighted (disregarding the drift of six miles, as the log gives no idea of its direction), places the ships at the latter time eighteen miles east of the middle of the Ragged Island chain. On sighting land, the explorers probably ran to the southwest, as the journal says that on the 26th they were anchored on the southern side of the islands.

On the 27th Columbus set sail for Cuba. As already stated, there can be hardly a doubt that he was anchored on Columbus Bank, south of what are now known as the Ragged Islands. Although this point is fixed with more certainty than any other in his cruise among the Bahamas, it is difficult to identify his landfall on the Cuban coast, as the ships lay off and on all night and were in the midst of a strong westerly current. Moreover, the description of the harbor they entered the next morning is very vague. Four ports have been selected as the harbor he made; Port Nipe, which has been chosen by Captain Becher and by Navarette, bears about S. by W. from the eastern end of Columbus Bank, on which the ships were at anchor on the 26th. The course steered therefrom was SSW., crossing moreover a westerly current. In order to bring them to Port Nipe, Captain Becher has to assume one and three-quarter points westerly variation. But as already stated, Mr. Chas. A. Schott of the Coast and Geodetic Survey has, after a careful investigation of all sources of information, decided that the variation of one-quarter of a point westerly was in all probability that found by Columbus. It is noticeable that the adoption of this variation agrees admirably with all bearings in the log capable of being identified. Such are the bearing of the rocky islet from Fernandina, and the general agreement of the dead reckoning from Isabela to Las Islas de Arena. There thus seem to be very strong reasons against adopting Captain Becher's assumed variation; and, unless this assumed variation be true, the ships could

never have reached Port Nipe. Varnhagen selected Port Gibura, and Fox, Port Padre, and either of these selections may be correct, as far as the dead reckoning is concerned. The only description of the port given in the log is that it had twelve fathoms at the entrance and had a wide channel. Mr. Fox condemns Port Gibura because it has only three fathoms, but his own selection of Port Padre conflicts with the journal in that it gives a long, narrow entrance. Neither of these spots can be definitely determined as Columbus' landfall. On the accompanying chart the preference is given to Port Gibura, as it seems more probable that in the interval of four hundred years which have lapsed since Columbus' visit, a channel should shoal, than that what he describes as a broad entrance should contract by the upheaval or movement of its shores into a narrow passage like the entrance of Port Padre, as shown on the charts of to-day. The fourth harbor chosen is that of Washington Irving's track, Boca de Caravela. The objections already stated to his track affect this selection as well.

In thus assigning a track for Columbus through the Bahamas in 1492, it is not pretended that it will fully satisfy all statements in the journal, or exactly agree with all details. If any track should ever be definitely accepted, it will be not because it agrees in every particular with the journal and other contemporaneous authorities, but because it agrees with them as *a whole.* The objections to the track proposed in this paper are principally to its selection of Rum Cay as Santa Maria ; but it is claimed that of the many statements made in the log, Rum Cay satisfies more than it disagrees with, and its selection as the second island enables the others to be fixed with exactness, there being hardly a question that can be raised against them. Whether we work forwards from Guanahani or backwards from Cuba, Rum Cay, disagreeing as it does only in size with the statements of the log, presents itself as Santa Maria, and explains many things before inexplicable, especially the record made by Columbus that he saw twenty leagues of Fernandina (Long Island) before he anchored off its shore.

There are a few things recorded in the journal that seem to be inexplicable by the assumption of any track that can be proposed. The first of these is the notice of the light seen at sea, four hours before Guanahani was sighted. This light cannot be located on any known land. In the track proposed by Washington Irving, a solution is given, but the subsequent great disagreements of his track with the journal prevent our accepting it, and we cannot but believe that the light was due to the imagination of Columbus, wrought up to a high

pitch by the numerous signs of land encountered that day. He admits himself that at first the light was so indistinct that he did not dare to affirm it to be on land, and that of the two persons he called to see it, only one succeeded in making it out. Any one who has had much experience in trying to see faint lights on a sea horizon with a moderate sea running, knows how easy it is to be deceived, especially when from any cause the senses are on the alert for a light one *wishes* to see. The only other supposition is that the light was in a canoe passing from one island to another; but as it was seen forty miles from San Salvador, and as there is no reason to suppose from an inspection of the journal or the old charts that there was any land outside of Guanahani, this seems improbable.

Another difficulty is found in the positive statement of Columbus that when he left San Salvador, so many islands came in sight that he did not know which to steer for, but finally chose the largest, although that was not the nearest. It is hard to imagine that he was deceived or that he construed clouds or indications of land into islands; but his language indicates the existence of an archipelago such as we cannot find anywhere on our maps of to-day, near the border of the Bahamas, except in the vicinity of the Caycos, and this cluster of islands is so situated that no track can be followed from them that agrees with any of the subsequent record. It seems better to admit that this passage cannot be understood, rather than to attempt any forced reconcilement. Columbus may have been deceived, or some error may have crept into the log later. As it stands, it is irreconcilable with modern charts.

Another point in the log that disagrees with every track thus far proposed, and apparently with every one that can be proposed, is an entry under date of November 20. Columbus there states his position as twenty-five leagues NE$\frac{3}{4}$N. from Puerto del Principe (supposed to be the present port of Tanamo), and says that he was then twelve leagues from Isabela, which was *eight leagues from San Salvador*. The position given on the accompanying chart for November 20, on Mr. Fox's track, agrees well with the distance of Isabela cited, but it seems impossible to reconcile the courses and distances of the log between the 12th and 20th of October with the declaration that Isabela and San Salvador are only eight leagues apart. This portion of the log is not the verbatim copy, but an abridgment by Las Casas, and this statement may be an error due to him, or it may possibly be due to carelessness in the original. While adopting

the log of Columbus as our authority, we evidently cannot reconcile all his statements; but the above seem to be utterly at variance with the others. They have never been explained satisfactorily and no attempt is here made at explanation; but attention is called to them that it may not appear that they have been neglected in deciding on the track proposed in this paper. As already stated, a track must be judged as a whole, and not by one or two of its strongest points. Reference has been made in several places to the possibility of a change of level in the Bahamas since 1492. There seems to be no evidence that such changes have occurred, and considerable evidence exists that none have taken place. The rocky islet north of Isabela (Bird Rock) would be connected with Crooked Island by a slight elevation, or completely submerged by a slight subsidence. Clarence Harbor is to-day shoal and intricate, as described by Columbus. He found shoal water for five or six leagues to the southward of the Ragged Islands, just as there is to-day. The adjacent lands, Florida, Cuba, and Hayti, have been inhabited by Spaniards and their descendants since the early part of the sixteenth century, but none of these lands show any marked change of level. It therefore appears unjustifiable to claim that the Bahamas of 1492 were more elevated than at present. Changes in the position of shores, depths of harbors, or character of the coasts probably have taken place under the action of surf and oceanic or tidal currents; but these changes would be but limited and might not be apparent.

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NAVAL TACTICS.

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Throughout the general advance in the arts and sciences, nowhere has progress been more marked, more continuous, than in naval architecture. From the line-of-battle ship of fifty years ago, to the modern mastless ironclad with ram bow, high speed, and few guns, is a long distance, marked by continuous change and improvement. In full and eager rivalry the guns have changed with the ships, from the old 32-pounders, along the line of smoothbore shell-guns and muzzle-loading rifles, until now the full-powered breech-loading steel gun cries halt to the constructor.

But with such radical changes in ships and guns, how slight have been the changes in the tactics for handling these ships and using these new weapons to the best advantage! A fond clinging to the traditions of the past signalizes most of the changes that have been made. It was some time after steam had been introduced before any change in the old system of naval tactics was attempted. The French were the first to put forth a clear, well-defined system of steam naval tactics. Upon their system ours is founded, and for purely evolutionary exercises it is, perhaps, all that is to be desired; but the changes in ships and in their armament during the last twenty years have, to my mind, made necessary as radical changes in the tactics of battle as were necessitated by the introduction of steam itself. The effect of these changes has been almost wholly ignored. Indeed, many of them have become established facts since our present steam tactics were written.

In the United States Naval Tactics there are only four signals having any reference to an order of battle, and there are virtually

only two formations: order of battle in two lines, and in two columns. The latter, we are told, is to be used by vessels whose main strength lies in their broadside batteries. It is hardly to be conceived, however, at the present day, that any Admiral commanding a fleet of modern vessels would receive an attack in this formation, exposing the broadsides of his fleet to the rams of his enemy, and trusting to his guns to stop them. The remainder of the four hundred and odd signals are purely evolutionary, having little reference to actual warfare, or only such reference as the exercises of the gymnasium have to the fitting of the athlete for the river or the ball-ground. I do not mean to depreciate the value of evolutionary tactics; on the contrary, their importance can hardly be exaggerated. Nor do I sympathize with a remark I heard made by an officer during the drill in the Bay of Florida some years ago, that it would have answered just as well to have gotten together a dozen steam-launches with the commanding officers in charge of them. That would have defeated the main object of the drill, which was more a school for the nerves than for the understanding. In a week's time any schoolboy could master the principles of our steam tactics; but the difficulty experienced in the Bay of Florida, and in later drills as well, from what I have heard, was to get one vessel within a cable's length of another and keep her there. To instruct commanding and other officers in the speed and turning power of their vessels, under varying circumstances of wind and weather; to accustom them to manœuvring these vessels at all speeds in close proximity to others; to train the eye, the judgment, and above all, the nerves—these seem to me the true objects of evolutionary drills, fitting the fleet, as the evolutions of the parade-ground do the battalion, for actual warfare, each however to be discarded when the serious business of war begins.

The French system of naval tactics and our own, as Commodore Parker says in his introduction, are simply an adaptation of military to naval tactics. The introduction of steam has, of course, added greatly to the mobility of our fleets, and to a great degree made such an adaptation practicable; but it appears to me that the military idea may be carried too far.

In Parker's Steam Fleet Tactics, and even in a recent English Naval Prize Essay, plans of battle are proposed, the principal ideas of which are concentration on one wing, doubling on one wing, feinting on one wing, and attacking another. These are manœuvres that are frequently carried out on shore under cover of woods or broken ground, but are hardly practicable at the present day in the open

sea and in the broad light of the sun. To gain the weather-gauge, to double on the van division and throw the rear or lee division out of action, were favorite manœuvres in the days of the old sailing vessels, and the brilliant success that has followed such strategy in the past still has its effect upon the tactics of to-day; but when we consider that hereafter fleets will go into action with a speed of at least ten knots, and that the right vessel of the largest fleet will be within easy range of the guns of the vessel on the left, it seems idle to talk of feinting on one wing and attacking the other, or to expect more than momentary advantage from concentration, at the expense, perhaps, of confusion and disorder in your own fleet. And here I will stop a moment to consider the great stress that is laid upon concentration; this seems to me a fallacy that we are most likely to fall into by following too closely the military idea. In the English Naval Prize Essay of 1880 (a very valuable paper), concentration is one of the main points insisted upon. In one instance given, of an imaginary naval battle of the future, B's fleet advances in column of vessels to attack A's fleet in line abreast (the favored formation). As soon as A discovers that it is B's intention to pierce his line in his present formation, he makes signal to his fleet, in accordance with a previous arrangement, and at the proper distance, determined by sextant, and after due consideration of the table of helm angles, he hauls down the signal, and the right and left wings simultaneously put their helms respectively to starboard and port. The result theoretically is the ramming of B's vessels, which, with a fatuity to be encountered only on paper, continue on their way; but, as the essayist in another place states that the difference between ramming and being rammed is only a ship's length, it seems more than probable that such a plan would bring the two wings of A's fleet together in dangerous, if not disastrous, confusion, and there would be as much likelihood of their ramming each other as of their ramming the enemy. A careful reading of a sextant, or an accurate application of the table of helm angles, at such a moment is hardly to be counted upon. I do not mean to discredit the usefulness of such tables, nor do I think there is any danger that we can know too much about such matters, or have too many scientific or mechanical aids to judgment. But it seems to me that the true time for the application of all these aids is during the evolutionary drills, all of which are simply to educate the eye and train the judgment of the captain for the time when he must throw aside such aids and act instantaneously, and without hesitation, upon the decision of the moment.

It is not, however, surprising that there should be a wide difference of opinion on the question of naval tactics ; the whole subject is purely tentative. There has been only one combat between fleets since the introduction of steam—the battle of Lissa. In that action the Austrians in line abreast, attacked the Italians in line ahead ; the latter appeared to have no especial plan of battle, while that of the Austrians seemed, as has been said by an English writer on naval tactics, very similar to those of Donnybrook Fair, "whenever you see a head, hit it." As far as tactical lessons go, there is little to be learned from Lissa, except perhaps the fact that to ram successfully, vessels must have speed and use it. The Austrians pierced the Italian line, but, strange to say, effected no damage in doing so. After this manœuvre the action became a general mêlée. The Austrian vessels, without any general order, devoted themselves principally to attempts to ram, some of them even securing their broadside batteries. From lack of speed and an impression that it was necessary to slow down or stop the engines before collision, most of these attempts were failures, the sinking of the Re d'Italia being the only marked success.

Out of this victory of the Austrians, however, has grown up a strong sentiment in favor of attacking in line abreast, some writers favoring the single line, others the double line, still more, perhaps, the double line indented (the formation prescribed in our tactics), while some propose even three lines, as in the "Carré Naval" of Admiral Bouet Willaumez, where a squadron of nine vessels is formed in three lines, three abreast, and this square is considered the tactical unit, certainly the perfection of concentration; but it seems to me impossible to imagine that such a fleet can be carried into action without being completely broken up and disorganized by the first shock. An accident to any one of the vessels of the first and second lines must cause those in rear to run into her, or, in their endeavors to avoid collision, to break up the square. To reform it in action would seem impossible. Remembering that the modern ironclad is generally a vessel of from six to nine thousand tons displacement, with ram bow, and a maintained speed of from ten to twelve knots, that ships in close order are only one hundred fathoms apart, it would seem a fundamental rule for all orders of battle that no vessel of a fleet should be in the water of another. Certainly, in the moment of going into action a commanding officer should not be required to keep his eyes glued to the speed-ball of the next ahead, and his nerves at a high tension to avoid a collision with his leader or being rammed by his next astern.

At the present time there are two distinct systems of tactics in use: 1st, that in which the single vessel is made the tactical unit, as it is with us; 2d, the group system. The latter originated with the French, and has been adopted in part and with modifications by the English. The idea is the subdivision of the fleet into groups, generally of three, which shall be manœuvred as units, the vessels of each group maintaining the same relations toward each other through all evolutions, Nos. 2 and 3 confining their attention simply to maintaining their positions relative to the group leader, who is responsible for the group. It is claimed that this gives greater mobility to a fleet, greater capacity for concentrating and dispersing, and especially greater facility for reforming during the confusion of battle. It seems to me such claims are well founded. At the same time there has been much difficulty experienced in handling these groups as single vessels, at least by the English, for, according to Captain Freemantle (Naval Prize Essay, 1880), it is prescribed in their manual that "when ships are in group formation, any signal which entails an alteration of course is to be acted upon by all the ships in each group together, unless otherwise ordered, and group formation is not to be resumed until signal to that effect is made." This certainly would seem to show that the groups, as arranged by the English, are not handily manœuvred. As far as I know, there has been little if any similar complaint from the French; this is due probably to the difference in formation of groups adopted, and their systems of manœuvring. The English group is in the form of a scalene triangle (Fig. 1), the French in the form of an equilateral triangle with the apex toward the enemy (Fig. 2).

Fig. 1

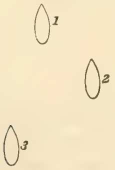
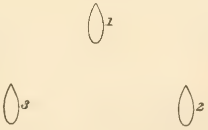


Fig. 2



In manœuvring their groups, the English have endeavored to handle Nos. 2 and 3 of each group by helm and variations of speed, so that throughout all evolutions they would maintain their position relative to No. 1. The difficulty of this is apparent; to accomplish it

would require the most careful management and the nicest calculations throughout. The French on the contrary have gone to the opposite extreme; Nos. 2 and 3 of their groups are required simply to gain their positions at the close of each evolution as best they can. As these orders apply to two-thirds of the vessels, it would seem as if a fleet must be very thoroughly exercised before evolutions can be performed without indecision, hesitation, and delay; unless well accustomed to work together, one commanding officer will naturally wait to see in what direction his consort will move before putting over his own helm. The French group formation or *peloton d'attaque* is criticized on the ground that Nos. 2 and 3 mutually mask each other's fire, while the scalene triangle, it is claimed, gives free use to each vessel of the group of her guns, ram, and torpedoes. In endeavoring to obtain all this, however, the English have sacrificed the mobility of the group, and consequently the very principle of the system, which makes it imperative that the groups should be handy and capable of being manœuvred as single vessels.

Firmly believing in the fundamental principle at the bottom of the group system, I would suggest that the groups consist of two vessels; in other words, that the fleet should be divided into pairs, mutually supporting and depending upon one another, the No. 1 of each pair in charge of, and responsible for, the movements of the two. There would be required only two original formations for the pairs as follows:

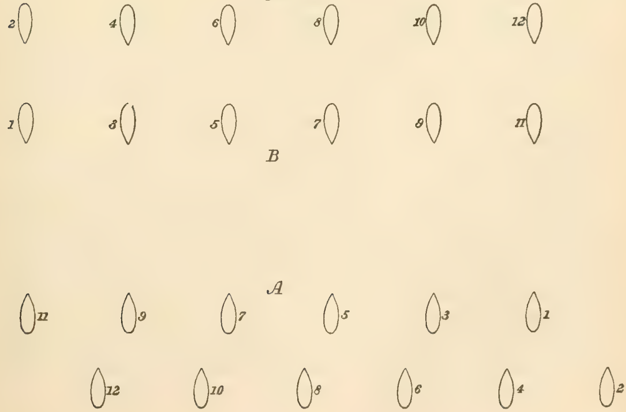
In either case the position of No. 2 would be four points abaft the beam, distant two cable's-lengths. All evolutions should be performed by the pairs without change of form unless otherwise signalled; No. 1 of each pair manœuvring in accordance with present tactics for single vessels, No. 2 placing herself in the proper position from No. 1 by the shortest possible route and without reference to any other vessel. This it seems to me will secure the greatest possible mobility, and at the same time, as the groups are entirely distinct, and there is no

provocation for No. 2 of one group to get in the way of No. 2 of another, this would obviate the indecision and danger likely to occur in following the same rule with the French groups of three. At the same time it seems to me as contrary to the true principle of the group system to require No. 2, in all evolutions, to move on a prescribed curve, as it would be to the true principles of military tactics to require a skirmish line in broken country to march with the regularity and precision of a battalion on review.

The value of this subdivision of a fleet into pairs seems to me capable of proof in many ways. It simplifies manœuvres, in that one-half of the fleet have no other duties to perform than to maintain their position in relation each to his own leader. Each leader of a pair will advance to the charge and use his ram or torpedo with more confidence, knowing that his consort is close at his back to support him if disabled, or aid him in overwhelming his adversary if successful. The reforming a fleet after once passing through the enemy's line will certainly be much simpler and shorter work if the vessels first group themselves in pairs.

Let us suppose two fleets of twelve vessels each advancing to the attack (Fig. 3), A in line abreast by pairs, B in two lines. It will be perceived that A's formation is virtually the same as the indented line or the "order of battle in two lines" of our own tactics; but to my mind the strength of the formation and the mobility of the fleet are greatly increased by its subdivision into pairs.

Fig. 3



Whatever may be the result of the next great naval war and the consequent tactics of the future, nothing seems better settled now than that in the next engagement of fleets the ram will be made the first and principal weapon, and fleets will, in one formation or another, advance on each other bows on. With this purpose we will suppose the two fleets A and B advancing at full speed. Should any or all of A's first line come into collision with B's first line, B's second line must get out of the way or ram their leaders. In doing this, should they put their helms a-starboard, they will present their broadsides to the rams of A's second line, the Nos. 2 of the pairs; should they put their helms a-port they will throw themselves out of position to render any assistance to their leaders, while the position of A's second line is the very best for assisting the first line, and as free as possible from danger of accidental collision. It is, however, after the fleets have passed through each other, after the crush and confusion of the first attack, when it is desirable to reform the lines, that the value of the formation in pairs is most decided. The fleet that can reform promptly and strike a decisive second blow before the enemy is ready, will in all probability win the victory, and to accomplish that is the real mission of tactics. And here the formation in pairs will have a marked advantage; one-half of the fleet has only to look out for its position relative to its leader, the difficulties of reforming are thus reduced one-half, and even if the fleet should become disorganized as a fleet, and the action become a general mêlée as at Lissa, the pairs, acting together, would certainly prove more effective than they could be, acting independently.

I am perfectly aware how easy it is to fight out battles on paper, how naturally the enemy does what you wish him to do, and how inevitable are the favorable results you desire; I will therefore refrain from carrying on this action any farther, though the temptation is strong and precedents are numerous and unexceptionable.

I will, however, repeat the statement made earlier in this paper, that a fleet in the formation of pairs in accordance with the plan I have proposed, could, in my opinion, be manœuvred with as much facility as a fleet of single vessels in all the more important evolutions of our signal book. To add the formation by pairs and the evolutions that would necessarily follow this change to our present authorized tactics, would require an addition of perhaps thirty, not more than forty, signals.

It is not proposed to replace or set aside the old tactics, but to add the formations and evolutions by pairs as a distinct drill, which will

bear a relation to the old tactics somewhat similar to the relation that the skirmish drill bears to the battalion drill in the infantry tactics. If desired, the old fleet organization could be retained; but I should prefer dropping the squadrons of four, and dividing a fleet of twelve vessels simply into two divisions of six, each division being, in accordance with the system, subdivided into three pairs. The squadron of four is not small enough to act as a unit of the group system, nor is it large enough for an independent command in a fleet so organized.

As formations for battle, fleets organized in pairs would probably make or receive an attack either in line by pairs (Fig. 3), or in columns of pairs abreast by divisions (Fig. 4), or in formation of pairs in open echelon (Fig. 5), each pair bearing, according to signal, one or two points abaft the beam of the one next on its right or left.

Fig. 3

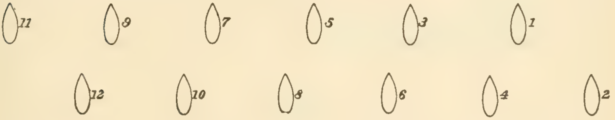


Fig. 4

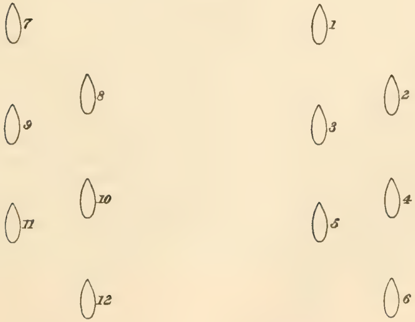
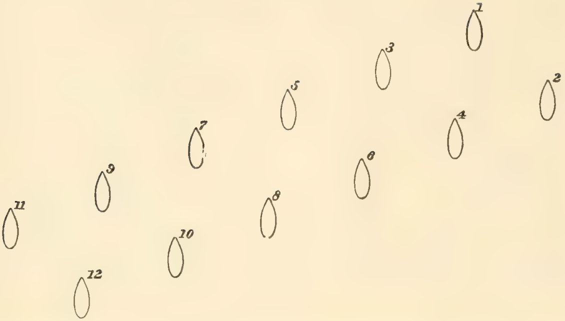


Fig. 5



I have written this paper more with the hope of exciting discussion and interest in this important subject, than with the expectation that my ideas will meet with general acceptance. In that hope, I trust I shall not be disappointed.

DISCUSSION.

THE CHAIRMAN.—The paper and the discussion have been highly interesting. But it is to be regretted that the author has not pursued the subject further and explained the evolutions and formations that are possible under his system of grouping.

In a naval engagement under steam, where both sides are anxious for battle, and where the contending vessels are rams and carry guns of great penetrating power, the result must be the destruction of such ships as are not well handled.

Imagine two fleets, or two single ships, approaching each other, each having a speed of ten knots; the resulting force of collision would be that due to a speed of twenty knots—one mile in three minutes. The crash would be terrific. Naturally, the commanding officers would make their best endeavors to seek rather than to avoid such an encounter. If, in addition to this, there were the possibility of being run into by his consort, we can imagine that the commanding officer's position would not be an enviable one.

The formation proposed by Lieutenant-Commander Elmer would, however, in a great degree preclude the possibility of such a contingency. The discussion of the paper has shown the great diversity of opinion on the subject of fleet and squadron manœuvres. Good results will undoubtedly follow from the consequent consideration that will be given it by those who take interest in the subject of the paper to which we have listened to-night.

I feel sure that all will join me in thanking the author for his valuable contribution to naval literature.

NAVAL INSTITUTE, ANNAPOLIS, MD.

April, 1884.

CYLINDER DIAMETERS OF MARINE COMPOUND ENGINES.

By Assistant Engineer Jay M. Whitham, U. S. N.

The following summary of the different methods of designing the cylinder diameters of marine compound engines is presented in the hope that it may be of interest to those engineers who have no access to the numerous publications on this subject. Two methods of design are here published for the first time, viz., that proposed by Mr. Rae and that proposed by the writer. In each method cited, the advantages and disadvantages are pointed out, while a comparison of all is given in the table under the heading "Summary." The appended table is here published complete for the first time, although the writer published a part of it in the *Journal of the Franklin Institute* for July, 1883. The table has most valuable data of the performances of over one hundred modern marine engines.

I. Analytical Methods of Design.

(*a*) *Method proposed by Passed Assistant Engineer Chas. W. Rae, U. S. N.*

The High-pressure Cylinder.

p_i = initial absolute pressure in the cylinder,

x = number of times steam is expanded in it,

p_t = terminal absolute pressure $= \dfrac{p_i}{x}$,

p_m = mean absolute pressure $= \dfrac{p_i}{x}(1 + \log_e x)$,

p_e = mean effective pressure $= p_m - p_t$.

(This condition ($p_e = p_m - p_t$) is obtained only when a constant back pressure equal to the terminal pressure is maintained in the cylinder.)

Therefore,

$$p_\epsilon = \frac{p_i}{x}(1 + \log_\epsilon x) - \frac{p_i}{x} = \frac{p_i}{x}\log_\epsilon x,$$

or,

$$\frac{p_\epsilon}{p_i} = \frac{\log_\epsilon x}{x}.$$

$\frac{p_\epsilon}{p_i}$ is the ratio of the mean effective to the initial absolute pressure in the high-pressure cylinder, and the greatest amount of work obtainable from the cylinder is when this ratio is a maximum.

From the above, we see that this ratio is equal to an expression $\frac{\log_\epsilon x}{x}$, in which x, the number of times the steam is expanded in the high-pressure cylinder, is the only unknown quantity; hence, if we solve this expression for such a value of x as will give $\frac{p_\epsilon}{p_i}$ a maximum value, we shall obtain the number of expansions, irrespective of pressure, that will give the greatest power obtainable from the high-pressure cylinder.

Let $$y = \frac{\log_\epsilon x}{x}; \text{ then } dy = \frac{x\frac{dx}{x} - \log_\epsilon x\, dx}{x^2},$$

whence, $$\frac{dy}{dx} = \frac{1 - \log_\epsilon x}{x^2} = 0, \text{ or, } \log_\epsilon x = 1.$$

Hence, $x = 2.71828 = \epsilon$.

This value of x is also the base of the Naperian system of logarithms, a natural result, as we have assumed the expansion curve to be that of a rectangular hyperbola.

For this value of x, $\frac{\log_\epsilon x}{x} = 0.36788$; therefore, the proper number of times to expand the steam in the high-pressure cylinder of a compound engine, to obtain the greatest possible amount of work from it, is 2.72 (nearly).

To reduce the above to the point of cutting off:

Assuming the clearance volume at each end of the high-pressure cylinder to be ten per centum of the stroke displacement of the piston, let us put

$s =$ stroke displacement of the piston,

$0.1s =$ clearance volume at one end,

$1.1s =$ total volume of steam at end of stroke,

$\frac{1.1s}{2.72} = 0.4044s =$ initial volume of steam per stroke,

$0.4044s - 0.1s = 0.3044s$ = initial volume of steam up to the point of cutting off in the cylinder proper.

Hence, with clearance-spaces at ends of cylinder equal to ten per centum of the stroke displacement of the piston, the point of cutting off in this cylinder, in order to give 2.72 expansions to the steam, is 0.3044 of the cylinder proper, or say, 0.3 *of the stroke from commencement.*

The Low-pressure Cylinder.

The size of the low-pressure cylinder depends upon one thing only, *i. e.*, the total number of expansions desired.

The following table gives the cylinder ratio for any number of total expansions from 12 to 5:

Total number of expansions of steam.	Number of expansions in high-pressure cylinder.	Cylinder ratio.
12	2.72	4.41
11	2.72	4.04
10	2.72	3.67
9	2.72	3.31
8	2.72	2.94
7	2.72	2.57
6	2.72	2.20
5	2.72	1.84

The method of procedure, then, to obtain the size of the cylinders of a compound engine, according to this plan, is as follows:

Find the weight of steam evaporated per unit of time at the maximum boiler pressure. Allow for the fall of pressure between boilers and cylinder, and also for difference between amount furnished by boilers, as per coal consumption, etc., and amount accounted for in the cylinder (*vide* Isherwood's "Experimental Researches in Steam Engineering").

We then have the initial weight, pressure, and, consequently, volume, of steam used per stroke in the cylinder. The volume of the cylinder is, therefore, 2.72 times as great. The stroke of the piston being governed by considerations of space, etc., and fixed, the area of the high-pressure piston is at once obtained. The above volume includes the clearance space of ten per centum of the stroke displacement.

Knowing the total number of expansions required, the size of the low-pressure cylinder is obtained from the table here given by finding the cylinder ratio in the third column.

This method is applicable only to engines fitted with an intermediate receiver, in which the pressure can be kept practically constant and equal to the terminal pressure in the high-pressure cylinder. Also, when the ratio of expansion is 2.72 in the high-pressure cylinder, the low-pressure cylinder follows full stroke.

Example.—Find the diameters of cylinders for the Galena from the following data: Two compound cylinders; crank at 90°; stroke, 3.5 feet; revolutions per minute, 65; initial absolute pressure of steam in boilers, 95 lbs., and 88 lbs. at cylinder; ratio of expansion, 5.32 [See "Summary"]; it is required to develop 1150 I. H. P., using 20 lbs. of steam per I. H. P. per hour.

Solution.

Pounds of steam used per minute $= \dfrac{20 \times 1150}{60} = 383.33.$

Pounds of steam used per stroke $= \dfrac{383.33}{130} = 2.95.$

Volume of one pound of saturated steam of 88 lbs. absolute pressure $= 4.9336$ cu. feet.

Area of high-pressure cylinder $= \dfrac{2.95 \times 4.9336 \times 144}{0.4044 \times 3.5} = 1481.2$ sq. ins.

Diameter of high-pressure cylinder $= 43\frac{7}{16}$ inches.

Ratio of cylinders $= \dfrac{5.32}{2.72} = 1.96.$

Area of low-pressure piston $= 1.96 \times 1481.2 = 2903.15$ sq. inches.

Diameter of low-pressure cylinder $= 60\frac{13}{16}$ inches.

(*b*) *Method in which there is no "Drop" in Pressure between the Cylinders.*

Let $A =$ area of high-pressure piston in square inches.

$B =$ area of low-pressure piston.

$x = B \div A =$ ratio of expansion in low-pressure cylinder.

$r =$ total ratio of expansion of steam in the engine.

$r \div x =$ ratio of expansion in the high-pressure cylinder when there is no "drop" between cylinders.

The work done in the high-pressure cylinder is proportional to

$$Ap_1 \left\{ \frac{1 + \log_\epsilon \dfrac{r}{x}}{\dfrac{r}{x}} - \frac{1}{\dfrac{r}{x}} \right\},$$

where $p_1 =$ initial absolute pressure of steam at the cylinder.

The total work, if done in one cylinder, is, neglecting back pressure, equal to

$$Bp_1\left\{\frac{1+\log_\epsilon r}{r}\right\}.$$

If the work done in each cylinder is the same,

$$Ap_1\left\{\frac{1+\log_\epsilon \frac{r}{x}}{\frac{r}{x}}-\frac{1}{\frac{r}{x}}\right\}=\frac{1}{2}\,Bp_1\left\{\frac{1+\log_\epsilon r}{r}\right\};$$

whence, $\quad \frac{x}{r}\log_\epsilon\frac{r}{x}=\frac{1}{2}\cdot\frac{x}{r}\cdot(1+\log_\epsilon r)$, since $\frac{B}{A}=x$;

or, $\quad \log_\epsilon r-\log_\epsilon x=\frac{1}{2}+\frac{1}{2}\log_\epsilon r$;

therefore, $\quad \log_\epsilon x=\frac{1}{2}[\log_\epsilon r-1]. \qquad (1)$

If the back-pressure, p_3, in the condenser is considered,

$$Ap_1\left\{\frac{1+\log_\epsilon \frac{r}{x}}{\frac{r}{x}}-\frac{1}{\frac{r}{x}}\right\}=\frac{1}{2}\,B\left\{p_1\left(\frac{1+\log_\epsilon r}{r}\right)-p_3\right\},$$

which reduces to

$$\log_\epsilon x=\frac{1}{2}\left\{\log_\epsilon r-1+\frac{p_3 r}{p_1}\right\}. \qquad (2)$$

Equation (2) is evidently more practical than (1), and enables the designer to find the ratio of the high-pressure cylinder to that of the low-pressure, as will be seen by the example below.

The method is short and simple, but not so practical as some of the others, as "drop" is not allowed for.

Example.—Find diameters of cylinders for the Galena from the following data: Two-cylinder compound engine; cranks at 90°; stroke, 3.5 feet; revolutions per minute, 65; initial absolute pressure of steam at boilers, 95 lbs.; ratio of expansion, 5.32; back pressure in the condenser, 5 lbs. absolute; it is required to develop 1150 I. H. P.

Solution.—Substituting value of r in (1), we have $x=1.4$, whereas r, p_1, and p_3 in (2) give $x=1.6$. Taking the latter as the more practical, we find that

$$\frac{1}{1.6}=\frac{\text{Area of high-pressure piston}}{\text{Area of low-pressure piston}}.$$

Calling initial steam pressure at cylinders 88 lbs.,

$$p_e = \text{mean effective pressure} = 88\left(\frac{1+\log_\epsilon 5.32}{5.32}\right)-5=39.16 \text{ lbs.}$$

$$B=\text{area of low-pressure piston}=\frac{1150\times 33000}{39.16\times 455}=2130.8 \text{ sq. ins.}$$

Diameter of low-pressure cylinder $= 52\frac{1}{8}$ inches.

Area of high-pressure piston $= \frac{2130.8}{1.6} = 1331.7$ sq. inches.

Diameter of high-pressure cylinder $= 41\frac{3}{16}$ inches.

(*c*) *Mr. R. B. Smith's Method.* [See "Engineering," Vol. 28, p. 380.]

In designing a compound engine, the first and main factor is the power developed during admission and expansion of one pound of steam at pressure p_1, temperature T_1, to a final temperature and pressure, T_2 and p_2.

Let $r =$ ratio of expansion $=$ final volume of 1 lb. of steam $\div$ initial volume of 1 lb. of steam.

$$p_m = \text{mean total pressure} = p_1\left(\frac{1 + \log_\epsilon r}{r}\right). \qquad (1)$$

$$\text{Theoretical H. P. of one pound of steam} = \frac{\frac{1}{12}\text{ final volume} \times p_m}{33000}. \qquad (2)$$

From this theoretical H. P. there is to be deducted a per cent equivalent to the following three principal causes of loss, viz.:

(1) Loss in p_1, due to friction in ports, etc., and motion of steam when admitted into high-pressure cylinder;

(2) Loss due to space between cylinders; and

(3) Loss due to back pressure in condenser.

The deduction to be made to cover all these losses Mr. Smith computes to be 21 per cent in the best constructed marine engines. Therefore, actual work derived from one pound of steam admitted at initial pressure p_1, and having a final pressure p_2, is $(100 - 21 =) 79$ per cent of the theoretical work; hence, 0.79 is a coefficient that expresses the efficiency of the engine.

The following shows how the power so gained is applied in order to find the diameters of cylinders of a given I. H. P.:

Volume of high-pressure cylinder at point of cut-off

$$= \frac{\text{volume of 1 pound of steam at pressure } p_1 \times \text{proposed I. H. P.}}{\text{actual I. H. P. of 1 pound of steam} \times \text{strokes per minute.}}$$

Volume of low-pressure cylinder $=$ volume of high-pressure cylinder at point of cut-off $\times\ r$.

Volume of the high-pressure cylinder $=$ volume of low-pressure cylinder divided by proposed ratio of cylinders.

Example.—Find diameters of cylinders for the Galena, from the following data: Two-cylinder compound engines; cranks at 90°;

stroke, 3.5 feet; revolutions per minute, 65; initial absolute pressure of steam at boilers, 95 lbs.; ratio of expansion, 5.32; and I. H. P. of engine to be 1150, with cylinder ratio of 2.95.

Solution.—Volume of 1 pound of steam at 95 lbs. absolute pressure $= 7931.5$ cubic inches.

Volume of 1 pound of steam at $\frac{95}{5.32}$ lbs. absolute pressure $=$ 38016.0 cubic inches.

$$p_m = 95\left(\frac{1 + \log_e 5.32}{5.32}\right) = 47.7 \text{ lbs.}$$

Theoretical H. P. of one pound of steam

$$= \frac{\frac{1}{12} \times 38016 \times 47.7}{33000} = 4.579.$$

Actual H. P. of one pound of steam $= 4.579 \times 0.79 = 3.617$.

$$\text{Steam used per stroke} = \frac{1150}{3.617 \times 130} = 2.446 \text{ lbs.}$$

Volume of high-pressure cylinder at point of cut-off

$$= 7931.5 \times 2.446 = 19400.45 \text{ cubic inches.}$$

Volume of low-pressure cylinder

$$= 19400.45 \times 5.32 = 103210.4 \text{ cubic inches.}$$

Area of low-pressure piston (since stroke is 42 inches)

$$= \frac{103210.4}{42} = 2457.4 \text{ square inches.}$$

Diameter of low-pressure cylinder $= 56$ inches (nearly).

Area of high-pressure piston (since 2.95 is cylinder ratio)

$$= \frac{2457.4}{2.95} = 833 \text{ square inches.}$$

Diameter of high-pressure cylinder $= 32\frac{7}{16}$ inches.

(*d*) *Rankine's Method.*

This method is similar to those already given, but differs in the fact that the cylinder ratio is $\sqrt{r}$, where $r =$ the total ratio of expansion. The method assumes that the "drop" is *nil;* and that the final pressure in each cylinder is equal to the back pressure, when, if the piston areas are proportioned in the ratio of $1 : \sqrt{r}$, the maximum stress will be the same on each piston.

Hence, in order to have equal expansion, equal initial stresses, and equal work performed in each cylinder, design the low-pressure cylinder as if all the work had been done in it; divide the area thus

obtained by the square root of the ratio of expansion, and the area of the high-pressure cylinder is found.

Example.—Find diameters of the cylinders for the Galena, having given the following data: Two-cylinder compound engine; cranks at 90°; stroke, 3.5 feet; revolutions per minute, 65; initial absolute pressure of steam at boilers, 95 lbs.; at cylinder, 88 lbs.; back pressure in condenser, 5 lbs. absolute; ratio of expansion, 5.32; and I. H. P., 1150.

Solution.—Mean effective pressure, if work is all done in one cylinder, $= 88\left(\frac{1 + \log_\epsilon 5.32}{5.32}\right) - 5 = 39.16$.

Area of low-pressure piston $= \frac{1150 \times 33000}{39.16 \times 130 \times 3.5} = 2130.8$ sq. ins.

Area of high-pressure piston $= \frac{2130.8}{\sqrt{5.32}} = 926.4$ square inches.

Whence,

Diameter of low-pressure cylinder $= 52\frac{1}{8}$ inches.

Diameter of high-pressure cylinder $= 34\frac{3}{8}$ inches.

(*e*) *Method of Mr. John Turnball, Jr.* [See "A Short Treatise on the Compound Engine," pp. 16, 17.]

To distribute the total power equally over the working parts of a compound engine, the initial stresses on the pistons and the work performed in each cylinder must be the same. Mr. Turnball accomplishes this by making the ratio of cylinders the same as the ratio of expansion of steam in the high-pressure cylinder.

Hence, if $A =$ area high-pressure piston,

$B =$ area low-pressure piston, and

$r =$ ratio of expansion of steam in each cylinder of the engine, then

$$B = rA.$$

Therefore, when $p_1 =$ initial pressure in high-pressure cylinder, and

$p_1' =$ initial pressure in low-pressure cylinder,

$$p_1 A = p_1' B;$$

that is, the initial tensions or stresses on the pistons are the same. When $p_2' =$ absolute pressure at the end of the stroke in the low-pressure cylinder, the total ratio of expansion of the steam is $\frac{p_1}{p_2'}$.

Hence, when the ratio of expansion is the same for each cylinder,

$r =$ ratio for either cylinder $= \sqrt{\dfrac{p_1}{p_2'}}$.

"From the nature of the compound engine, the area opened up for the steam by the movement of the large piston is at all times decreased by a proportionate movement of the small piston, amounting to $\dfrac{B}{Ar} = 1$, so that the space actually occupied by the expanding steam $= B - 1$; and from this we get the formula for ascertaining the average pressure in the low-pressure cylinder of a compound engine."

$p'_m =$ average pressure in low-pressure cylinder $= p_1' \left(\dfrac{\log_\epsilon r}{r - 1} \right)$.

The mean pressure would be $p_1 \left\{ \dfrac{1 + \log_\epsilon \left(\dfrac{p_1}{p_2'} \right)}{\dfrac{p_1}{p_2'}} \right\}$, if all the work were done in the low-pressure cylinder; hence, the mean pressure in the high-pressure cylinder is

$$p_1 \left\{ \frac{1 + \log_\epsilon \left(\dfrac{p_1}{p_2'} \right)}{\dfrac{p_1}{p_2'}} \right\} - p_1' \left\{ \frac{\log_\epsilon r}{r - 1} \right\}.$$

Example.—Find diameters of cylinders for the Galena, given the following data: Two-cylinder compound engine; cranks at 90°; stroke, 3.5 feet; revolutions per minute, 65; initial absolute pressure of steam at boilers, 95 lbs.; at cylinder, 88 lbs.; back pressure in condenser, 5 lbs. absolute; ratio of expansion, 5.32; and I. H. P., 1150.

Solution.—Ratio of expansion in each cylinder $= \sqrt{5.32} = 2.307$.

Terminal pressure in low-pressure cylinder $= \dfrac{88}{5.32} = 16.54$.

Initial pressure in low-pressure cylinder $= 2.307 \times 16.54 = 38.16$.

Mean effective pressure in low-pressure cylinder

$$= 38.16 \left(\frac{\log_\epsilon 2.307}{2.307 - 1} \right) - 5 = 19.24.$$

Area of low-pressure piston in order to develop one-half the work in that cylinder

$$= \frac{\dfrac{1150}{2} \times 33000}{130 \times 3.5 \times 19.24} = 2167.5 \text{ square inches.}$$

Diameter of low-pressure cylinder $= 52\frac{1}{2}$ inches.

Area of high-pressure piston $= \dfrac{2167.5}{\sqrt{5.32}} = 942.4$ square inches.

Diameter of high-pressure cylinder $= 34\frac{5}{8}$ inches.

(*f*) *Prof. A. E. Seaton's Method.* [See "A Manual of Marine Engineering," by Seaton, pp. 95, 96, 97, 103, and 104.]

Let $p_1 =$ absolute initial pressure of steam.
$p_r =$ absolute receiver pressure of steam.
$p_3 =$ absolute condenser pressure, or back pressure in low-pressure cylinder.
$R =$ ratio of cylinders.
$r =$ total ratio of expansion.
$r_h =$ ratio of expansion in high-pressure cylinder.
$r_l =$ ratio of expansion in low-pressure cylinder.
$p'_m =$ mean total pressure due to r_h and p_1.
$p''_m =$ mean total pressure due to r_l and p_r.
$p_m =$ mean total pressure due to r and p_1.
$p'_e =$ mean effective pressure in high-pressure cylinder $= p'_m - p_r$.
$p''_e =$ mean effective pressure in low-pressure cylinder $= p''_m - p_3$.

Also,
$$p_m = p_1\left(\frac{1 + \log_\epsilon r}{r}\right),$$
$$p'_m = p_1\left(\frac{1 + \log_\epsilon r_h}{r_h}\right),$$
and
$$p''_m = p_r\left(\frac{1 + \log_\epsilon r_l}{r_l}\right).$$

But since the work is to be equally divided between the cylinders,
$$p'_m - p_r = R(p''_m - p_3). \qquad (1)$$

And if there is no loss from "drop," and if the mean pressure in the high- is referred to the mean pressure in the low-pressure cylinder, we shall have
$$\frac{p'_m - p_r}{R} + p''_m - p_3 = p_m - p_3,$$
which, combined with (1), gives
$$\left.\begin{aligned} p''_m - p_3 &= \frac{1}{2}(p_m - p_3) \\ \text{and} \quad p'_m - p_r &= \frac{R}{2}(p_m - p_3) \end{aligned}\right\} \qquad (2)$$

When x denotes the efficiency of the system, $(1-x)$ is the part of loss due to "drop"; whence,

$$\left.\begin{aligned} p''_m - p_3 &= \frac{x}{2}(p_m - p_3) \\ \text{and}\qquad p'_m - p_r &= \frac{xR}{2}(p_m - p_3). \end{aligned}\right\} \qquad (3)$$

"To find the *actual* mean pressures when there is loss due to 'drop,' the value of x must be determined: this may be done by substituting the value of p'_m and p''_m found from the preceding formulae; but an approximate value may be found by determining the value of p_r in (3); from the value thus found calculate p''_m, referring the mean pressures of both cylinders to the low-pressure cylinder. If $(P_m - p_3)$ be the equivalent mean pressure thus found, then, approximately,"

$$x = \frac{P_m - p_3}{p_m - p_3}. \qquad (4)$$

Example.—Find diameters of cylinders for the Galena, given the following data: Two-cylinder compound engine; cranks at 90°; stroke, 3.5 feet; revolutions per minute, 65; initial absolute pressure of steam at boilers, 95 lbs.; at cylinder, 88 lbs.; back pressure in condenser, 5 lbs.; ratio of expansion, 5.32; ratio of cylinders, 2.95; and I. H. P., 1150.

Solution.

$$p_m = 88 \times \frac{1 + \log_\epsilon 5.32}{5.32} = 44.16 \text{ lbs.}$$

$$r_h = \frac{5.32}{2.95} = 1.8.$$

$$p'_m = 88 \times \frac{1 + \log_\epsilon 1.8}{1.8} = 77.58.$$

$$p_r = 77.58 - \frac{2.95}{2}(44.16 - 5) = 19.82 \text{ lbs.}$$

From (3), therefore,

$$p'_e = 77.58 - 19.82 = 57.76,$$

$$r_l = \frac{p_r r}{p_1} = \frac{19.82 \times 5.32}{88} = 1.2,$$

$$p''_m = 19.82 \times \frac{1 + \log_\epsilon 1.2}{1.2} = 19.52,$$

and

$$p''_e = 19.52 - 5 = 14.52.$$

When referred to one cylinder alone,

$$P_m - p_3 = 14.52 + \frac{57.76}{2.95} = 33.76,$$

and $\quad p_m - p_3 = 44.16 - 5 = 39.16.$

Therefore,
$$x = \frac{33.76}{39.16} = 0.862.$$

Hence,
$$\text{actual } p_e' = 0.862\,(44.16 - 5)\,\frac{2.95}{2} = 49.69 \text{ lbs.},$$

$$\text{actual } p_e'' = \frac{0.862}{2}\,(44.16 - 5) = 16.88 \text{ lbs.},$$

and actual
$$p_r = 77.58 - \frac{2.95}{2}\,(33.76) = 27.5 \text{ lbs.}$$

The values of p_e, p_e'', and p_r, although given as actual values, are not practically correct, but may be called the *theoretical mean pressures*. In actual practice, however, these pressures will be changed on account of a variety of causes, which, in a marine engine, are chiefly:

(1) Friction in stop-valves on boilers and engine and in pipes connecting these.

(2) Friction or "wire-drawing" of the steam during admission and cut-off.

(3) Liquefaction of steam during admission and expansion.

(4) Exhausting before the piston has reached the end of the stroke.

(5) Compression, and back pressure due to lead.

(6) Friction in steam-ports, passages, and pipes.

(7) Clearance.

"It will be seen, then, that the actual mean pressure expected to be obtained from the indicator-diagram of an engine depends upon the proportion and arrangement of the cylinders and their valves, etc.; and in calculating the *expected* mean pressure from the *theoretical mean pressure*, due allowance must be made in each individual case."

"If the mean pressure be calculated by the methods here given, and the necessary corrections made for clearance and compression, the expected mean pressure may be found by multiplying the results by the factor in the following table:

Particulars of Engine.	Factor.
(1) Expansive engine, special valve gear, or with a separate cut-off valve, cylinders jacketed, . . .	0.94
(2) Expansive engine, having large ports, etc., and good ordinary valves, cylinders jacketed, . . .	0.90 to 0.92
(3) Expansive engines with the ordinary valves and gear, as in general practice, and unjacketed, . .	0.80 to 0.85
(4) Compound engine with expansion valve to H. P. cylinder; cylinders jacketed, large ports, etc., .	0.90 to 0.92

(5) Compound engines with ordinary slide-valves, cylinders jacketed, good ports, etc., ...	0.80 to 0.85
(6) Compound engines with early cut-offs in both cylinders, without jackets and expansion valves, as in general practice in the merchant service, . . .	0.70 to 0.80
(7) Fast-running engines of the types and design usually fitted in war ships, ...	0.60 to 0.80

"If no correction be made for the effects of clearance and compression, and the engine is in accordance with general modern practice, the clearance and compression being proportionate, then the theoretical mean pressure may be multiplied by 0.96, and the product again multiplied by the proper factor in the table above, the result being the expected mean pressure."

Hence the mean effective pressure in the high-pressure cylinder, instead of being 49.69 lbs., will be

$$49.69 \times 0.96 \times 0.8 = 38.16 \text{ lbs.,}$$

by assuming the Galena to belong to the best type under class 7 in the table.

Similarly, the mean effective pressure in the low-pressure cylinder will be $16.88 \times 0.96 \times 0.8 = 12.96$ lbs.

Substituting the values found, and taking 575 as the horse-power to be developed in each cylinder, we find that the area of the low-pressure piston is $\dfrac{575 \times 33000}{130 \times 3.5 \times 12.96} = 3216.5$ square inches,

and the diameter of the low-pressure cylinder $= 64$ inches.

The area of the high-pressure piston

$$= \frac{575 \times 33000}{130 \times 3.5 \times 38.16} = 1092.8 \text{ square inches,}$$

which is also $\dfrac{3216.5}{2.95}$; hence, the diameter of the high-pressure cylinder is $37\frac{5}{16}$ inches.

(*g*) *Method proposed by the Writer.* [See appended Table.]

All the methods here given depend for their application upon one or more coefficients deduced from successful practice, so that the writer offers another method deduced from successful practice as illustrated in the appended table.

The method is illustrated in its application to the design of cylinder

diameters for the horizontal, two-cylinder, receiver engine of the Galena, which has the following data: Stroke, 42 inches; revolutions per minute, 65; piston speed, 455 feet per minute; initial gauge pressure of steam, 80 lbs.; back pressure in condenser, 5 lbs., and I. H. P., 1150.

In the appended table, under the heading "Horizontal Compound Engines," the average piston speed is 544 feet per minute, cylinder ratio, 2.95, initial absolute pressure of steam, $(70 + 15 =)$ 85 lbs., and the I. H. P. developed per cubic foot of low-pressure cylinder volume is 18.23. Mr. Isherwood says, in his "Report on the U. S. S. Alarm," made to the Bureau of Steam Engineering, Navy Department, that the I. H. P. $\propto$ (mean effective pressure)$^{\frac{3}{2}}$ $\propto$ (revolutions)^3. (See also p. 648 of Sennett's "Marine Steam Engine.")

Now, if we wish to design a horizontal compound engine which will conform to successful practice, as represented in the table, we must modify this 18.23 I. H. P. in accordance with the variations in pressure and speed.

If, in the table, we take 6.35 as the average ratio of expansion, the mean effective pressure, if all the work is done in the large cylinder, is 32 lbs. when the condenser pressure is 5 lbs. This 6.35 is about the average expansion of the steam in the cases given when the total ratio varies as (cylinder ratio)^2, as found in Turnball's method, and, also, with the initial pressure as given in Mr. Chas. E. Emery's formula, deduced from his experiments with the U. S. Revenue steamers in 1874 and 1875, viz.:

$$\text{ratio of expansion} = \frac{22 + \text{initial absolute pressure}}{22}.$$

Then, calling p_e the mean effective pressure, if all the work had been done in the large cylinder, and S the piston speed in feet per minute, the factor for pressure variation is

$$\left(\frac{p_e}{32}\right)^{\frac{3}{2}},$$

and for variations in piston speed,

$$\left(\frac{S}{544}\right)^3.$$

Hence, volume of the large cylinder in cubic feet is

$$\frac{\text{I. H. P.}}{18.23\left(\frac{p_e}{32}\right)^{\frac{3}{2}}\left(\frac{S}{544}\right)^3},$$

and the area of the low-pressure piston in square inches is

$$\frac{\dfrac{\text{I. H. P.}}{18.23\left(\dfrac{p_e}{32}\right)^{\frac{3}{2}}\left(\dfrac{S}{544}\right)^3}}{\text{Stroke in feet}} \times 144 = \frac{A \times \text{I. H. P.}}{\text{Stroke} \times p_e^{\frac{3}{2}} \times S^3}, \qquad (1)$$

where A is a constant whose common logarithm is 11.36209.
For the Galena,

$$\text{ratio of expansion} = \frac{22 + 95}{22} = 5.32\text{; hence,}$$

$$p_e = 95\left(\frac{1 + \log_e 5.32}{5.32}\right) - 5 = 39.16 \text{ lbs.}$$

Therefore, the area of the low-pressure piston is

$$\frac{1150 \times A}{3.5 \times (39.16)^{\frac{3}{2}} \times (455)^3} = 3277 \text{ square inches.}$$

Diameter of low-pressure cylinder is $64\frac{9}{16}$ inches.

Area of the high-pressure piston is

$$\frac{\text{Area of low-pressure piston}}{\text{Desired cylinder ratio}} = \frac{3277}{2.95} = 1111 \text{ square inches.}$$

Diameter of high-pressure cylinder is $37\frac{5}{8}$ inches.

In the "Compound Engine" by Mr. A. Mallet, it is clearly shown that within certain limits the cylinder ratio may be anything we wish, so that the ratio of cylinders will not affect formula (1), when we have fixed power, or when we use an expansion valve on the large cylinder.

For equal initial stresses the receiver pressure must be

$$\frac{95 \times 1111}{3277} = \frac{95}{2.95} = 32 \text{ lbs. (nearly).}$$

The number of expansions in the high-pressure cylinder will be $\left(\frac{5.32}{2.95}\right) = 1.8$, and, if clearance is ten per cent, the steam must be cut off at $\frac{1.1 \times 42}{1.8} - 0.1 \times 42 = 21.5$ inches from commencement, or at about half-stroke. Hence, we see that the work may be divided between the cylinders by means of the low-pressure expansion valve.

In a similar manner, the following formula has been deduced from the table, for the design of vertical compound engines, viz.:

Area of low-pressure piston in square inches

$$= \frac{\text{I. H. P.} \times A'}{(p_e)^{\frac{3}{2}}\ (S)^3 \times \text{stroke in feet}} \qquad (2)$$

in which p_e = mean effective pressure of steam whose initial absolute pressure is p_1, and expansion ratio r.

S = piston speed in feet per minute.

A' = a number whose common logarithm is 11.63976.

Area of high-pressure piston in square inches

$$= \frac{\text{Area of low-pressure piston}}{\text{Ratio of cylinders}}.$$

Formula (2) has been deduced by taking as our constants those found in the appended table, under the head of "Vertical Compound Engines." The constants are 569 for piston speed, I. H. P. per cubic foot of low-pressure cylinder, 14.9, and initial absolute pressure, 80 lbs. The cylinder ratio recommended for vertical engines is from 3.0 to 3.3; and for horizontal engines, from 2.5 to 3.0.

Comparing the horizontal and vertical types of engines, we see that in successful practice, the revolutions of the shaft are about the same in each case, and that the former have not so high a piston speed as the latter on account of the long stroke admissible with vertical engines.

The horizontal engines belong chiefly to war ships, and, as in each type the engines were developing their maximum power, the vertical engines are the more economical. Hence, the I. H. P. per cubic foot of the low-pressure cylinder volume is, at full power, greater for war than for merchant vessels, as the former care for economy at reduced rather than at full speeds.

II. Graphical Methods of Design.

(*a*) *Equal Expansion and Equal Work in each Cylinder.* [See Plate I.]

Lay down a diagram corresponding to the ratio of expansion and pressures used as if it were for a single cylinder, using all the steam and developing the power required; then divide the diagram by the line XY (as shown in Plate I.), so that the areas A and B shall be equal.

The mean ordinate of A will be the mean effective pressure in the high-pressure cylinder; and that of B, the mean effective pressure on so much of the low-pressure piston as is left after subtracting from it the area of the small piston. Hence, the total area of the large piston is the sum of the area so found and that of the high-pressure piston.

Example.—Find the cylinder diameters for the receiver, two-cylinder engine of the Galena, with the following data: I. H. P, 1150; stroke, 3.5 feet; revolutions per minute, 65; initial absolute pressure of steam, 95 lbs.; back pressure, 5 lbs.; and ratio of expansion, 5.32 with clearance of ten per cent.

PLATE 1.

ILLUSTRATING GRAPHIC METHOD No. 1

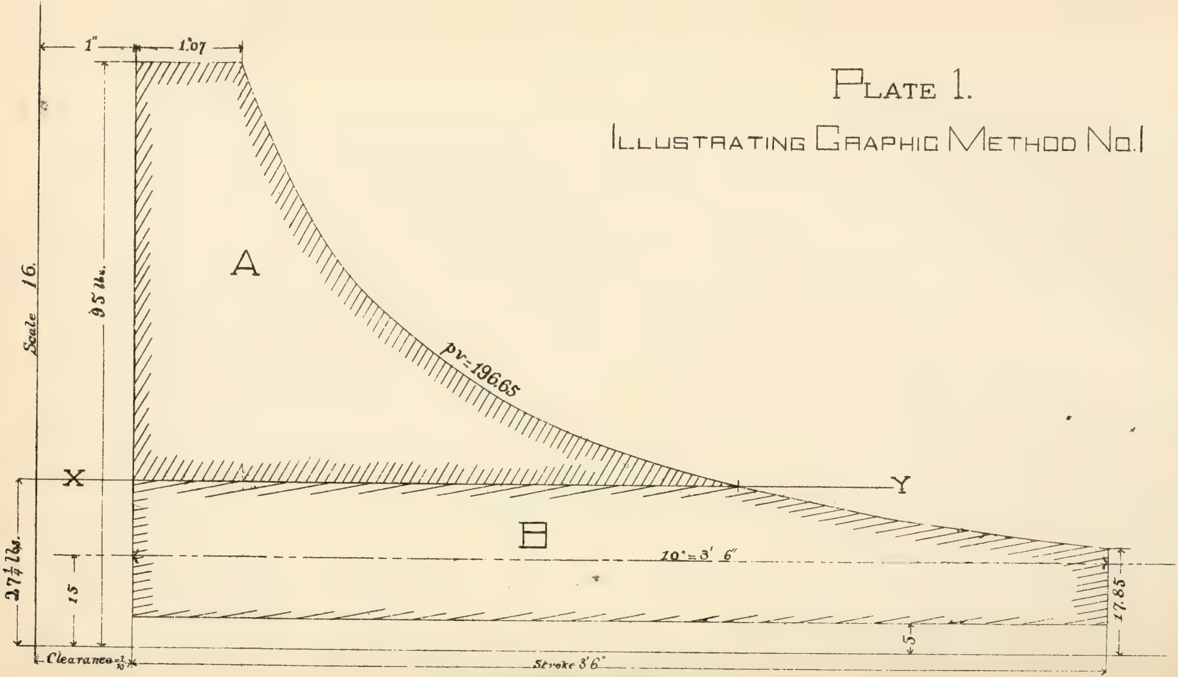
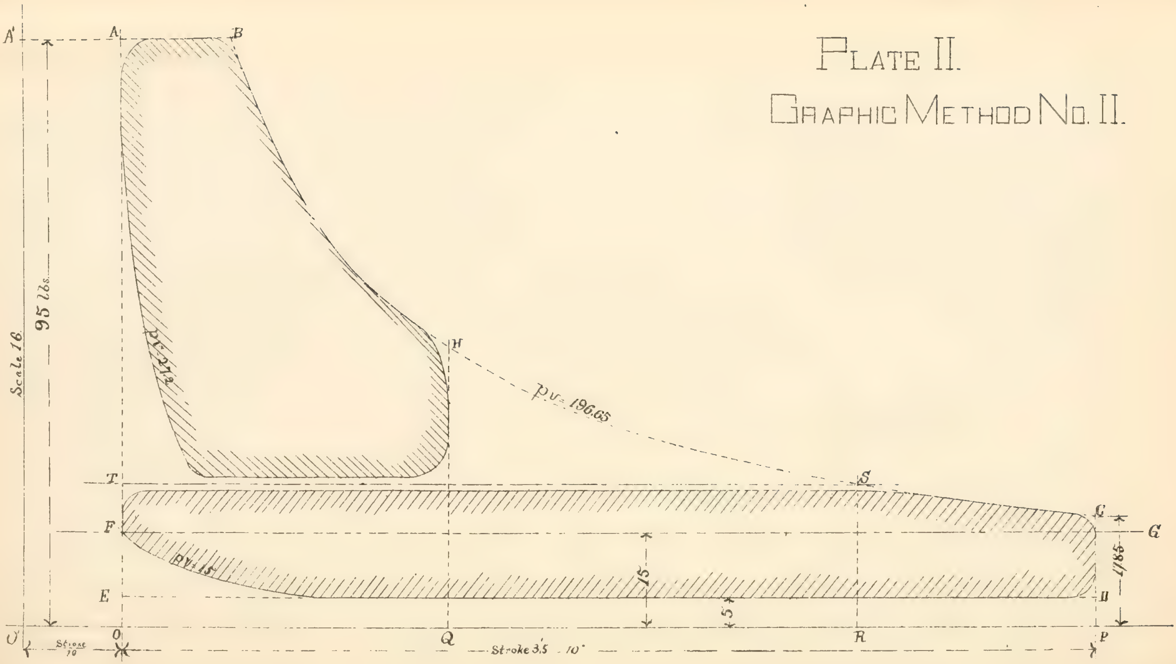


Plate II.

Graphic Method No. II.



Solution.—[See Plate I.] The mean pressure of the card A is 29.8 lbs. Hence, if the work is equally divided between the two cylinders, the area of the high-pressure piston is

$$\frac{575 \times 33000}{455 \times 29.8} = 1303.32 \text{ square inches.}$$

The diameter of the high-pressure cylinder is $40\frac{3}{4}$ inches.

The mean pressure of the card B is 19.75 lbs. Hence, if the work is equally divided between the two cylinders, the area of the low-pressure piston *minus* the area of the high-pressure piston, is

$$\frac{575 \times 33000}{455 \times 19.75} = 2111.68 \text{ square inches.}$$

Hence, the area of the large piston is $2111.68 + 1303.32 = 3415$ square inches, and its diameter is $65\frac{7}{8}$ inches.

[NOTE.—Chief Engineer Wm. H. Harris, U. S. N., using a back pressure of four pounds, divided the card by the line XY, so that the mean pressures found gave the exact diameter of the Galena's cylinders.]

(*b*) *Method in which "Drop" is Considered.*

[See Sennett's "Marine Steam Engine," pp. 496, 497.]

"Draw the theoretical diagram $ABCDE$ [see Plate II.] representing the action of the steam on the supposition that the whole of the expansion is done in the low-pressure cylinder, OP being the zero and FG the atmospheric lines, OA the initial absolute pressure of steam, and $\frac{OP}{AB}$ the total apparent rate of expansion in the cylinders, neglecting clearance." In drawing the curve, Plate II., the clearance has been taken as ten per cent; hence, the actual ratio of expansion is $\frac{O'P}{A'B}$. Assuming the point of cut-off in the low-pressure cylinder, the line ST is found, which will divide the card into two areas; then, assuming the ratio of cylinders, the line HQ is drawn. Next round off all the corners as shown; then the card will be similar to the combined card from compound engines. The mean effective pressure of this combined card is the mean pressure on the large piston supposing all the work to be done in the low-pressure cylinder. Knowing this, the area of the large piston is found, and then that of the high-pressure piston, as shown in the following:

Example.—Find cylinder diameters for the two-cylinder, receiver

engine of the Galena when the I. H. P. is 1150; stroke, 3.5 feet; revolutions per minute, 65; initial absolute pressure of steam, 95 lbs.; back pressure, 5 lbs.; rate of expansion of steam, 5.32; and clearance, ten per cent.

Solution.—(See Plate II.) Assuming ratio of cylinders as 2.95, and the point of cut-off at three-fourths stroke, the effective pressure of the combined card is 31.125 lbs., which will give for the area of the large piston

$$\frac{1150 \times 33000}{455 \times 31.125} = 2688.17 \text{ square inches.}$$

The mean pressure of the lower part of the combined card is 15.925 lbs., which gives for the area of the large piston

$$\frac{575 \times 33000}{455 \times 15.925} = 2622.80 \text{ square inches.}$$

The former value gives for the area of the high-pressure piston $\frac{2688.17}{2.95} = 911.24$ square inches; while the latter value gives an area of $\frac{2622.8}{2.95} = 889.08$ square inches. The mean effective pressure of the upper part of the combined card in Plate II. is 45 lbs., which gives an area of $\frac{575 \times 33000}{455 \times 45} = 926.75$ square inches for the small piston. Here we see that the results check, and we may take as the area of the small piston 911.24 square inches, corresponding to a diameter of $34\frac{1}{16}$ inches; and 2688.17 square inches for the low-pressure piston, giving a diameter of $58\frac{1}{2}$ inches.

III. Summary.

A comparison of the diameter of the Galena's cylinders, as found by the different methods, is shown in the table below. Judging the different methods by the results shown, analytical methods (*a*), (*f*), and (*g*), and graphical methods (*a*) and (*b*) would appear to be more practical, and hence more valuable than the others.

Had we taken the cylinder ratio as 2.32 instead of 2.95, there would have been but little difference between the high-pressure cylinder diameters. The ratio of expansion 5.32 is taken from the formula,

$$\text{Rate of expansion} = \frac{22 + \text{initial absolute pressure}}{22}.$$

This formula, deduced by Mr. Emery from experiments with U. S. Revenue steamers, has been verified by Messrs. J. S. Van Veen and

H. M. Van Aadel, Constructors to the Royal Dutch Navy. [See *Engineering*, June 9, 1882.]

The table is as follows:

Method of design.	Diameter of high-pressure cylinder.	Diameter of low-pressure cylinder.
Analytical.		
(*a*)	$43\frac{7}{16}$ inches.	$60\frac{13}{16}$ inches.
(*b*)	$41\frac{3}{16}$ "	$52\frac{1}{8}$ "
(*c*)	$32\frac{7}{16}$ "	56 "
(*d*)	$34\frac{3}{8}$ "	$52\frac{1}{8}$ "
(*e*)	$34\frac{5}{8}$ "	$52\frac{1}{2}$ "
(*f*)	$37\frac{5}{16}$ "	64 "
(*g*)	$37\frac{5}{8}$ "	$64\frac{9}{16}$ "
Graphical.		
(*a*)	$40\frac{3}{4}$ "	$65\frac{7}{8}$ "
(*b*)	$34\frac{1}{16}$ "	$58\frac{1}{2}$ "
Actual Diameters.	42 "	64 "

In every case of design, the theoretical indicator diagram, according to the principles illustrated in the Appendix to Sennett's "Marine Steam Engine," should be drawn so that the results may check and the performance of the engine may be all that can be expected.

[illegible]											[illegible]
S.S. Hu[illegible]	2	[illegible]	1.55	9.32	75	6	0	69	525	Edwards' "American Marine Engines"	
										do	
Compound [illegible] Engines											
H.M.S. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2	[illegible]	[illegible]	[illegible]	R. U. S. Inst. Pro., Vol. [illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	2	[illegible]	[illegible]	[illegible]	[illegible]	3	3	[illegible]	[illegible]	R. U. S. Inst. Pro., Vol. 2	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4	0	[illegible]	[illegible]	King's "War Ships of the World"	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10.0	[illegible]	2	9	[illegible]	[illegible]	do
[illegible]	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2	[illegible]	[illegible]	[illegible]	R. U. S. Inst. Pro., Vol. [illegible]
[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4	[illegible]	[illegible]	56[illegible]	King's "War Ships of the World"
Spartan		[illegible]	[illegible]	[illegible]	[illegible]	60	2	9	100.3	557.7	do
Tourmaline	2	[illegible]	2.41	[illegible]	10.23	60	2	9	95.5	520.0	do
[illegible]	2	[illegible]	[illegible]	[illegible]	10.12	[illegible]	2	9	[illegible]	[illegible]	
U.S.S. [illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	6	70	[illegible]	Edwards' "American Marine Engines"
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	6	65	455[illegible]	do (Inclined Engines)
[illegible]		[illegible]	[illegible]	[illegible]	14.25	[illegible]	3	[illegible]	[illegible]	455[illegible]	King's "War Ships of the World"
[illegible]	3	[illegible]	3.55	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	do
Averages			2.15		[illegible]	7				544	
Vertical [illegible] Engines											
T.C. Torpedo Boat, Thornycroft		[illegible]	[illegible]	[illegible]	31.6	120	1	0	438	[illegible]	R. U. S. Inst. Pro., Vol. [illegible]
H.M.S. Agamemnon	6	[illegible]	4.0	[illegible]	[illegible]	[illegible]	3	3	86	55[illegible]	do
[illegible]	3	[illegible]	[illegible]	[illegible]	[illegible]		3	0	80	[illegible]	King's "War Ships of the World"
[illegible]	4	[illegible]	[illegible]	[illegible]	[illegible]	60	2	6	104.9	[illegible]	do (Tandem)
Dreadnought	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	60	4	6	67.13	[illegible]	R. U. S. Inst. Pro., Vol. [illegible]
Euphrates	2	[illegible]	[illegible]	[illegible]	[illegible]	60	4	0	[illegible]	[illegible]	King's "War Ships of the World"
[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4	6	51.7	465.1	do
[illegible]	6	[illegible]	3.31	[illegible]	11.40	[illegible]	4	0	73	[illegible]	do
Nelson	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	6	80	560.0	R. U. S. Inst. Pro., Vol. [illegible]
Northampton	[illegible]	[illegible]	[illegible]	[illegible]	19.35	[illegible]	3	3	84	[illegible]	do
Temeraire	4	[illegible]	[illegible]	[illegible]	14.30	60	3	[illegible]	78.75	[illegible]	do
French—Adm. Duperré	6	[illegible]	3.30	[illegible]	16.74		3	3.1	77	[illegible]	King's "War Ships of the World"
Italian—the Colombo	3			3782			3	1.5	[illegible]	[illegible]	do
Dandolo	4	[illegible]	[illegible]	[illegible]	12.58	90	4	0	[illegible]	[illegible]	do
Torpedo Boat							1	4	[illegible]	[illegible]	Engineering, Vol. 33, p. 339 (Yarrow)
I.R.S. [illegible]	2	[illegible]	[illegible]	[illegible]	[illegible]		1	6	[illegible]	[illegible]	King's "War Ships of the World"
Asia	2	1-34 / 1-56	2.71	1050	17.56		3	6	66	462.0	do
Europe	2	1-42 / 1-73	3.02	1800	14.63		4	3	65	552.5	do
Zaliska	2	1-34 / 1-59	3.01	1470	31.82	70	3	0	92	551.0	do
S.S. Aberdeen	3	1-3 / 4? / 70	5.14	2086	17.38		4	6	65.5	589.5	Engineering, Vol. 33
Assyrian Monarch	2	1-46 / 1-8[illegible]	3.58	2400	12.2[illegible]		4	9	57	541.[illegible]	do Vol. 31
City of Pekin	4	2-51 / 2-88	2.97	3448	9.08	60	4	6	53	477.0	Edwards' "American Marine Engines"
City of San Francisco	2	1-51 / 1-85	2.07	1513	7.17	80	5	0	55	550.0	do
Germanic	1	1-48 / 1-83	3.[illegible]0	5000	13.30		5	0	55	550.0	Goodeve's "Steam Engine"
Iberia	3	[illegible] / 2-[illegible]8	3.88	4131	12.15	60	5	0	69	690.0	Engineer, September, 1879
Gitana	3	1-13½ / 1-15	2.47				1	4	230	666.7	Engineering, Vol. 32 (Yacht)
Inchrhona	2	1-35 / 1-68	3.75	1327	14.00		3	9	66	495.[illegible]	do
La France	3	[illegible]59[illegible]	4.6[illegible]				4	1.24	58	[illegible]	Engineer, 1882
Leila	2	1-[illegible] / 1-16	1.16	150	71.43		1	6	221.5	664.5	Herreshoff's Yacht
Lord of the Isles	2	1-44 / 1-76	3.00	1745	13.87	65	4	0	63	504.0	Engineer, February, 187[illegible]
Loudoun Castle	2	1-45 / 1-85	3.13	2400		70	4	0			do May, 1877
Moor	2	1-51 / 1-90	3.115	4250	11.23		5	0	69.75	697.5	Engineering, Vol. 33
Mytho	3	1-55 / 2-[illegible]	2.40	2640		57	3	3½	66	434.1	Engineer, October, 187[illegible]
Ohio	2	[illegible]	2.46	1978	11.14		4	0	60	480.0	Edwards' "American Marine Engines"
Orient	3	1-60 / 2-85	4.01	5200	13.20		5	0	58	580.0	Engineer, September, 1879
Parisian	3	1-60 / 2-85	4.01	6020	15.30		5	0	85	850.0	Engineering, Vol. 32
Servia	3	1-72 / 2-100	3.86	10350	11.60		6	6	53	689.0	do Vol. 33, p. 349
Stirling Castle	3	1-63 / 2-90	4.08	8500	17.50		5	6	66.5	731.5	do do
Ville d'Oran	2	1-42 / 1-[illegible]	3.63	2100			4	0			Engineer, August, 188[illegible]
Wanderer	2	1-25 / 1-50	4.00	717	20.49		2	6	99	495.0	Engineering, Vol. 31 (Yacht)
From the Table of Receiver Compound Engines compiled by Mr. F. C. Marshall, of Newcastle-on-Tyne, and published in *Engineering*, Vol. 32, p. [illegible]	2	1-42 / 1-80	3.63	1881	13.48		4	0	69	552.0	
	2	1-50 / 1-[illegible]	2.16	2077	14.72		4	6	60	540.0	
	2	1-54 / 1-94	3.03	2207	9.41		5	0	53	530.0	
	2	1-51 / 1-88	2.97	2745	13.00		5	0	59	590.0	
	[illegible]	1-34½ / 1-[illegible]	3.44	[illegible]	11.25		3	5	71.3	[illegible]	
	2	1-48 / 1-84	3.07	2300	11.95		5	0	55	550.0	
	2	1-36 / 1-[illegible]	3.60	2500	10.80		4	5	56	504.0	
	2	1-30 / [illegible]	3.7[illegible]	1600	16.00		3	9	74.6	560.0	
	2	1-[illegible] / -68	3.57	1250	14.20		3	6	75.7	530.0	
	2	1-3 / 1-[illegible]	3.45	1230	14.35		3	[illegible]	75.7	530.0	
	4	1-48 / 2-03	3.00	4000	13.03		5	0	52.3	523.0	
	4	1-[illegible]8 / 2-40	4.38	1900	10.80		4	0	56	534.0	
	3	1-62 / 2-90	4.23	6300	15.84		5	6	55	605.0	
Averages	—		3.10		14.00	64				563.0	
Average piston speed of 104 engines										551.0	

PROFESSIONAL NOTES.

THE CARE OF BOILERS IN THE NAVY.

By Assistant Engineer W. M. Parks, U. S. N.

To any one at all familiar with the subject, it must be evident that the lifetime of boilers fitted to the vessels of our Navy is too short, and that the cost of repairs during their brief period of service is far greater than the nature of their duty would seem to warrant. Our boilers are well built and are made of the best materials; therefore we should expect a maximum of efficiency and length of service.

That we do not realize these expectations is generally conceded.

In this paper I purpose to show what means are taken for the preservation of our boilers, and to offer suggestions, not original, perhaps, but such as have not yet been acted upon.

In a pamphlet entitled "Instructions to Commanding and Engineer Officers," published by the Navy Department about four years ago, will be found a number of instructions in regard to the care of the machinery of vessels-of-war. Those relating to boilers are, briefly, as follows:

1. The use of zinc in the boilers.
2. The use of Crane's Mineral Oil, or its equivalent, in the cylinders.
3. Dry-pipes and drum-drains to be kept clear.
4. Empty boilers to be kept dry, free from ashes, scale, and rust; and also to be kept well painted.
5. Boilers not to be used as water tanks for fresh water, nor for trimming ship.
6. Exteriors of the boilers to be kept dry; fire-room bilges to be kept dry and well white-washed.
7. Sudden changes of temperature to be avoided; and when time will permit, at least three hours should be occupied in raising steam from cold water.
8. When not under steam, a cover to be fitted to the smoke-pipe.
9. Uptakes to be kept clean and well painted.
10. After fires are hauled, and before blowing the water out of the boilers, the furnaces and ash-pits are to be closed.
11. Surface-blows are to be used as rarely as possible, in order to prevent blowing out the mineral oil floating on the surface of the water.

It will we seen that nearly all of these instructions are intended to prevent corrosion in some one of the many forms in which it has usually appeared. Properly carried out, these instructions have proved successful. We hear very little complaint of corrosion now; the great trouble seems to be the rapid and disastrous formation of scale in the boilers. In some cases, before the boilers have made one cruise they are choked up with scale. The familiar results follow: leaky tubes and burned sheets, with the consequent expense and delay.

Let us examine the case of a vessel cruising under the present instructions. We will suppose that she is beginning a passage, and that she is to be under

steam for a week. Twenty-four hours after leaving port, this vessel is found industriously blowing quantities of highly-heated water into the sea, while an equal volume of much colder water is pumped into the boilers to take its place. This continues while the vessel is under steam. Thousands of gallons of sea-water pass through the boilers, each gallon depositing its share of scale.

This early and continuous use of the blow-valve is to some extent due to the condenser. With the hot-well relief-valves, as at present arranged, more or less leakage occurs from the salt-water side.

The principal cause, however, of this continual "blowing off" is to be found in the following paragraph, contained in the Steam Log-Books furnished to all steamers of the Navy:

Under "Explanations and Directions" we find: "With boiler pressures below 15 lbs. per square inch, the concentration of water in the boilers must not be allowed to exceed $\frac{2}{32}$; over that pressure, it must not exceed $\frac{1\frac{3}{4}}{32}$." This practically limits the concentration to $1\frac{3}{4}$, as pressures of 15 lbs. are rarely used now. This limit of concentration is far too low. It does not appear to be supported by theory, and is inconsistent with the best modern practice. Of all the traditions of earlier practice that still remain with us, it is safe to say that this "$1\frac{3}{4}$" limit is the most harmful. Its rigid enforcement is the principal cause of the inefficiency and short life of our boilers, to say nothing of the tons of coal wasted. We have the authority of Consté for the statement that sea-water, at a temperature of 255° F., corresponding to a pressure of thirty-two pounds above the atmosphere, is very near the point of saturation, so far as the sulphate of lime is concerned. This sulphate of lime is the principal ingredient of the scale so abundantly deposited in our boilers. With boilers worked at pressures greater than thirty-two pounds, it is evident that the greater the quantity of sea-water admitted, the greater will be the deposit of scale. Remembering this fact, the pernicious effect of a low limit of concentration is apparent. All modern authorities say that, within certain limits, the amount of scale deposited in a boiler does not depend upon the density maintained, but upon the quantity of water passing through the boiler. It is a fact that merchant steamers make ten-day passages across the Atlantic without opening a blow-valve. The loss from leakage and other causes is supplied from the sea. The density of the water in the boilers reaches from $\frac{4}{32}$ to $\frac{5}{32}$, but no such deposit of scale takes place as is frequently found in boilers where the density is not allowed to exceed $\frac{1\frac{3}{4}}{32}$.

If there is any doubt as to the propriety of changing the "direction" quoted from the Steam Log-Book, it is a subject well worthy of experimental investigation. Two boilers working under the actual conditions of sea-service, one carrying the water at $\frac{1\frac{3}{4}}{32}$, and the other, $\frac{2}{32}$ or $\frac{3}{32}$ higher, would determine whether we are still justified in annually blowing thousands of dollars into the sea, and in spending thousands more in repairs made necessary by this needless "blowing."

But to return to our vessel. If the engines are stopped without sufficient warning, something must be done to check the rapidly rising steam pressure. I have heard of instances where the use of the safety-valve was prohibited. At any rate, it is generally understood that the rush of steam from the escape-pipe is a nuisance. For that reason, every time the engines are stopped the blow-valves are opened wider, and the auxiliary pump is used to supply *cold* water to the boilers. Steam blowing furiously from the escape-pipe certainly is a great nuisance; not only that, but there results a waste of fresh water. This is only one of the many reasons why all vessels should have independent air and circulating pumps.

To sum up, I suggest the following means, in addition to those quoted in the

first part of this paper, to prolong the useful life of our boilers, and to increase their efficiency:

I. Such change in the "Directions" contained in the Steam Log-Books as shall permit the concentration of water in the boilers to be carried at a point much higher than at present allowed.

It is probable that, with the present more or less defective circulation of the water in boilers using high pressures of steam, the limit of concentration should be about $\frac{4}{32}$.

II. The boilers to be filled with fresh water whenever possible.

There are few ports in which good fresh water cannot be bought. It is only in connection with a high degree of concentration that the greatest benefit can be had from the frequent purchase of fresh water.

III. An auxiliary boiler to be supplied, for heating ship, distilling water, &c.

The arguments in favor of an auxiliary boiler are well known. Space can more readily be made for one if it is remembered that an auxiliary boiler need not be placed below the water-line.

In addition, I would suggest that the arrangement of hot-well relief-valves, as fitted to many vessels of our Navy, might be so changed as to render leakage of sea-water into the hot-well less liable to occur. Starting out with boilers filled with fresh water, a vessel should be able to steam from six to ten days without opening a blow-valve. This assumes a condenser at least moderately tight, and a limit of concentration of about $\frac{4\frac{1}{2}}{32}$. Steaming for six or ten consecutive days is rather the exception than the rule. But suppose steaming to continue longer. The high limit of concentration results in a saving of fuel; less sea-water passes through the boilers, and consequently a smaller deposit of scale is found. After arriving in port the boilers should be allowed to cool; they should then be pumped out, and refilled with fresh water.

TRANSLATION OF THE PAMPHLET "APPARELHO AUTOMATICO PORTUGUEZ PARA ARRIAR ESCALERES AS MAR COM TODO O TEMPO" (1883).

[Portuguese Automatic Apparatus for Lowering Boats in any Weather.]

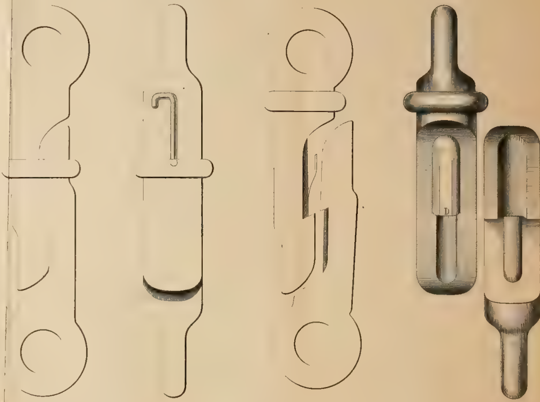
By Ensign Albert G. Winterhalter, U. S. N.

The apparatus is composed of two similar pieces placed together in an inverted position; one piece being made fast to the breech of the lower block of the boat's fall, or having the block simply hooked into it; the other piece being secured in the stern to the chain-span, and in the bow, to the link into which, ordinarily, the fall hooks.

A simple inspection of the apparatus renders its description superfluous, it being hardly necessary to remark that the outer part of the piece which is fast to the boat must always remain turned towards the bow of the ship, whether it be hoisted on side or stern davits. This condition fulfilled and the falls running smoothly on the sheaves, the apparatus will work automatically without the least trouble.

The part of the apparatus which is fast in the bows must be a little clear of the stem, that it may not foul in falling or on being detached; it is also necessary that the fitting be kept taut and as nearly as possible at right angles to the apparatus, which can be easily done.

PORTUGUESE AUTOMATIC BOAT DETACHING APPARATUS.



first part of this paper, to prolong the useful life of our boilers, and to increase their efficiency :

I. Such change in the "Directions" contained in the Steam Log-Books as shall permit the concentration of water in the boilers to be carried at a point much higher than at present allowed.

It is probable that, with the present more or less defective circulation of the water in boilers using high pressures of steam, the limit of concentration should be about $\frac{4}{32}$.

II. The boilers to be filled with fresh water whenever possible.

There are few ports in which good fresh water cannot be bought. It is only in connection with a high degree of concentration that the greatest benefit can be had from the frequent purchase of fresh water.

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TRANSLATION OF THE PAMPHLET "APPARELHO AUTOMATICO PORTUGUEZ PARA ARRIAR ESCALERES AS MAR COM TODO O TEMPO" (1883).

[PORTUGUESE AUTOMATIC APPARATUS FOR LOWERING BOATS IN ANY WEATHER.]

By ENSIGN ALBERT G. WINTERHALTER, U. S. N.

The apparatus is composed of two similar pieces placed together in an inverted position ; one piece being made fast to the breech of the lower block of the boat's fall, or having the block simply hooked into it ; the other piece being secured in the stern to the chain-span, and in the bow, to the link into which, ordinarily, the fall hooks.

A simple inspection of the apparatus renders its description superfluous, it being hardly necessary to remark that the outer part of the piece which is fast to the boat must always remain turned towards the bow of the ship, whether it be hoisted on side or stern davits. This condition fulfilled and the falls running smoothly on the sheaves, the apparatus will work automatically without the least trouble.

The part of the apparatus which is fast in the bows must be a little clear of the stem, that it may not foul in falling or on being detached ; it is also necessary that the fitting be kept taut and as nearly as possible at right angles to the apparatus, which can be easily done.

When, from the great heel of the vessel, you are not afraid that the boat may touch the side, you can, as soon as the fall begins to lower, hang the ring of the apparatus, drawing it up and letting it fall to the bottom of the shorter branch of the groove, which is seen on the upper part of the apparatus. In the contrary case (with little heel) it must be raised to this position only when the boat is very near the water. If, however, you wish to withdraw the ring, the apparatus can be held securely by the hand without much trouble, care being taken to let it go as soon as the boat touches the water.

The motion of the sea and the heel of the ship to the side on which the boat is being lowered, assist in a great measure the good working of the apparatus. The greater the weight of the boat and the faster the rendering of the falls, the more below its normal line of flotation will the boat sink on first striking the water; when it assumes the normal, it gives the falls a reaction which, though it be as small in height as 0.001 m., will instantly separate the two parts of the apparatus.

This apparatus was constructed in our Naval Arsenal. If it surpasses in any way the apparatus of Lavel, Ramsteris, or Clifford, constructed for a similar purpose, the good finish and perfect modelling will be owing to the workmen and foremen of the moulding and foundry shops.

MANSFIELD'S HYDRAULIC EXCAVATING-MACHINE.

By Lieutenant E. de F. Heald, U. S. N.

This machine, the invention of Mr. Samuel M. Mansfield, of Galveston, Texas, commends itself strongly to those interested in the subject of preserving our harbors from obstructions. Its primary recommendation is its convenience in handling and transportation; it does not require a craft specially designed and constructed for dredging. It can be used on any tug or steamer having a submerged propeller.

In the accompanying Fig. 1, *C* represents a pair of shears, whose head projects over the stern of the vessel. From the shear-head, a purchase supports the water-jet tube, with rose (*G*) and jets (*H*). The water-jet tube is connected with a flexible tube (*E*), which is in turn connected with the delivery pipe (*F*) of a powerful steam-pump. The flexible tube allows play in all directions.

Fig. 2 represents the ship moored by four (or six) anchors from the bows; two planted on the bows and two on the quarters, thus allowing shifts of position. Steam ready, the engines and pump are started. The jets of water forced through the rose-jets or nipples, loosen the mud or sand of the bottom, and hold the particles suspended in the water till they are carried off by the current induced by the propeller. As the work progresses, the vessel's position is changed by means of the cables and the rudder.

The capacity for work of a well-constructed machine, with pump of sufficient power, is not yet demonstrated. At Galveston, recently, 650 cubic yards of sand per hour were removed; but on this occasion the pump was a poor one, and could do only one-half the required amount of work.

The water-jet tube is preferably of iron, and should be about six inches in diameter; but other material may be used, and the diameter may be varied. The inventor used to good advantage four nipples or rose-jets, of one and one-half inch bore, placed two feet apart, thus obtaining a sweep of eight feet. While not rigidly prescribing a vertical position for the tube, the inventor feels assured that the best results follow when it is used in that position.

This machine, besides being simple in construction and effectual in operation, is particularly adapted for use in rough water, and where there are opposing currents; in fine, where the use of other constructions is impracticable.

Fig. 1.

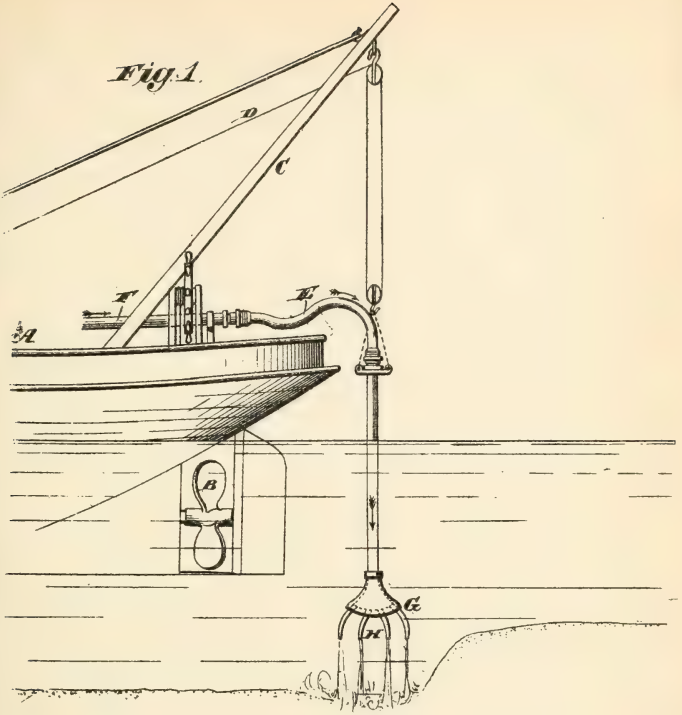
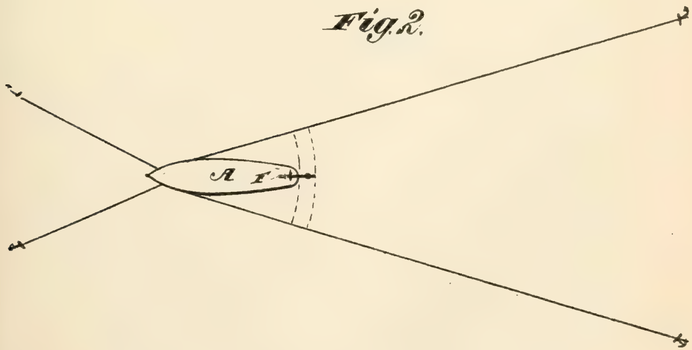


Fig. 2.



ISAAC FRIEDENWALD PHOTO LITHO. BALTO.

BIBLIOGRAPHIC NOTES.

ANNALEN DER HYDROGRAPHIE UND MARITIMEN METEOROLOGIE.

PART XII., 1883. The three Norwegian expeditions, 1876–78. Trials with registering log apparatus, and the ordinary log extracts from cruise report of S. M. S. Marie to the South Georgian Islands and back to Montevideo. Voyage of the German bark Humbold from Newcastle, N. S. W., to Hong Kong. Voyage of the German bark Niagara. Corrections to the charts of the Gulf of California, and determination by astronomical observations of the geographical positions of several points on the west coast of Mexico. Log notes of numerous German vessels. Comparison of the weather of North America and Central Europe for September, 1883. Brief hydrographic notices, meteorological, and magnetic tables for November, 1883. Track chart of German men-of-war Moltke, Elisabeth, and Carola.

PART I., 1884. Thunderstorms and hail formation. The "Boca" of Buenos Ayres. Voyages of the brig Felix between Great Britain and Nickerie, Dutch Guayana. Log notes of German vessels. Deep-sea soundings and temperatures of the U. S. S. Enterprise in the Indian Ocean, summer of 1883. Hurricanes in the S. Pacific Ocean on March 18-19, 1883. Brief hydrographic notices. Meteorological and magnetic tables for December, 1883. Comparison of the weather of North America and Central Europe for October, 1883.

PART II. Concerning thunderstorms and hail formation. Compass compensation by means of a vertical soft-iron cylinder. Concerning changes of deviation from considerable change of magnetic latitude. The changes in Sunda Straits caused by the volcanic eruption of August 26–28, 1883, in and near the island of Krakatoa. Deep-sea soundings of the Talisman in the Atlantic Ocean, summer of 1883. Deep-sea soundings of the U. S. Fish Commission Steamer Albatross in the North Atlantic Ocean, March to November, 1883. Comparison of the weather of North America and Central Europe for November, 1883. Brief hydrographic notices, meteorological and magnetic tables.

AMERICAN CHEMICAL JOURNAL, DECEMBER, 1883.

Memoranda of methods employed by fishermen for "barking" sails and in other ways preserving nets and sails, is the title of an interesting article on the means employed in staining sails the dingy, reddish-brown color often seen on the fishing boats of Scotland, Newfoundland, and about the foggy coasts of other countries.

TRANSACTIONS OF THE AMERICAN INSTITUTE OF CIVIL ENGINEERS, NOVEMBER, 1883.

The Cost of Steam Power, by Charles E. Emery, C. E.

TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS, VOL. XI., 1883.

The Anthracite Coal Beds of Pennsylvania.

Gives results of the State survey, and estimates the amount of anthracite coal produced in Pennsylvania from 1820 to 1881 as 478,052,629 tons. For 1881, the amount produced was 30,537,581 tons.

The Bower-Barff process.

In the Barff process, superheated steam is used to produce the coating of magnetic oxide on the surface of iron. In the Bower process, hot gases are used, the flame first oxidizing to produce Fe_2O_3 and then reducing to produce Fe_3O_4.

Barff's process is more suitable for wrought iron, while for cast iron, especially that rich in carbon, Bower's process is superior. Whitworth found that steel treated by Barff's method underwent no alteration in strength whatever.

BULLETIN OF THE AMERICAN GEOGRAPHICAL SOCIETY, No. 3, 1883.

Remarks Explanatory as to "The Sun, Planet, and Star Instrument," by Horatio Allen, Esq.

The First Landing on Wrangel Island, with some Remarks on the Northern Inhabitants, by Irving C. Rosse, M. D.

PROCEEDINGS OF THE AMERICAN PHILOSOPHICAL SOCIETY, April, 1883 to January, 1884.

Aerial Ships, by Russell Thayer.

The author proposes to make use of the reactive force of a powerful jet of air, gas, or vapor, acting rearward under pressure, for propelling air ships. A drawing of, and data for, such a ship to be driven by compressed air, are given.

BROAD ARROW, March 1, 1884.

A proposed select committee on naval administration.

It is announced that a Select Committee will be appointed to inquire into the subject of naval administration. The scope of the inquiry will be considerable, though in the first place it will be restricted to the repairs executed in the Royal Dockyards upon vessels of war. The idea seems to be, that the present system entails a larger and yearly-increasing loss upon the country, and that the committee will be able to check this outlay. Another object of the inquiry will be to settle the vexed question of shipbuilding in private and Government yards. The conviction is being yearly forced upon the attention of Parliament that Government should be its own shipbuilder, and this point it is intended to bring before the committee.

ENGINEER.

February 1, 1884. On the Physical Condition of Iron and Steel, by Prof. D. E. Hughes, F. R. S.

The instrument used in the experiments, the electric balance, is extremely sensitive to all molecular changes in metallic bodies. It shows that annealing not only produces softness in iron, and consequent molecular freedom, but it entirely frees it from all strains previously introduced by drawing or hammering. Thus a bar of iron drawn or hammered has a peculiar structure—say a fibrous one, which gives greater mechanical strength in one direction than in another. This bar, if thoroughly annealed at high temperature, becomes homogeneous in all directions, and has no longer even traces of its previous strains, provided there has been no actual mechanical separation into a distinct series of fibres.

The results of the author's researches may be thus formulated: 1. The highest degree of softness in any variety of iron and steel is that obtained by a rapid heating to the highest temperature less than fusion, followed by cooling in a medium incapable of changing its chemical composition. 2. The time required for gradual cooling varies directly as the amount of carbon in alloy. Thus in absolutely pure iron, rapid cooling would not harden it; whilst steel might require several hours, or days, even for pieces one millimetre in diameter. Slow cooling has no injurious effect upon iron when cooled in a neutral field; consequently, where time is no object, slow cooling may be employed in every case. A wire or piece of iron thoroughly annealed should not be bent, stretched, hammered, or filed.

The Valve-Gear of Marine Engines.

In a editorial commenting on the number of eccentrics, links, &c., used in the valve-gear of a modern compound engine, the question is asked, is all this really necessary? A link motion for a compound engine is a costly affair to begin with, and it very speedily gets out of order; not to such an extent as to entail any risk perhaps, but enough to spoil diagrams to some extent, and to give trouble to engineers. With the link motion there are three distinct places all liable to wear and become loose: viz., the joint between the eccentric rod and the link; the link-block, which readily becomes loose in the link; and the joint between the link-block and the valve-rod. If the link motion were dispensed with, then there might be but one joint, that between the valve-rod and eccentric, to wear or to be attended to. It is questionable if anything more is wanted than such a modification of the old shifting eccentric as will permit the engine to be handled rapidly; and this problem presents not the slightest difficulty.

To the locomotive, the link motion is admirably adapted, because it is used as an expansion gear. There is little or nothing in common between the use of the link at sea and on land; and it is to be regretted that this fact is overlooked. As an expansion and reversing gear combined, Stephenson's link is an elegant device; as a reversing gear alone it is a costly and clumsy expedient. If, however, it is impossible for marine engineers to persuade themselves that one eccentric is enough for one cylinder, it would be better to resort to the old locomotive gab gear, in use before the link was invented. With it the eccentric out of use during a voyage could at least do no harm, and a far more direct action of the valve would be obtained than is possible with the link.

FEBRUARY 8. Some Relations of Heat to Voltaic and Thermo-Electric Actions of Metals in Electrolytes, by G. Gore, F. R. S., LL. D.

A paper read before the Royal Society, describing experiments which throw considerable light upon the real cause of the voltaic current.

FEBRUARY 15. Description of the engines of H. M. S. Colossus.

The Colossus is propelled by two sets of inverted three-cylinder compound engines, each set having cylinders placed side by side. The high-pressure cylinders are 58 in. and the low-pressure cylinders 74 in. in diameter, while the stroke is 3 ft. 6 in. The total power contracted for is 6000 horses. The crank-shafts are of iron and made in three parts, which are interchangeable, the cranks being placed at an angle of 120° with each other. The propeller shafting is hollow and is manufactured of Whitworth's fluid-compressed steel; while the propellers are of manganese bronze. To give an idea of the complicated nature of a modern ironclad and of the responsibility which devolves upon the engineer officers, it may be mentioned that in the Colossus there are no fewer than thirty-six separate engines in addition to the main engines which propel the ship. These are a steering engine—three dynamo engines—two pumping engines for working the Normandy condenser—two circulating engines—two engines for actuating the exhaust fans—four engines for the supply fans—one

fire engine—two bilge donkey engines—four auxiliary feed engines—two hydraulic pumping engines—four hydraulic engines for turning the turrets—one capstan engine—one engine for driving the machinery in the engineer's workshop—two ash hoisting engines and five boat-hoisting engines. The whole of the auxiliary engines exhaust their steam into a separate auxiliary condenser. This arrangement with the special means fitted for allowing the steam from the boilers to pass into the main surface condenser, when the ship is suddenly stopped, prevents the rush and noise of steam passing through the escape-pipe on deck.

Speed Experiments with Ship's Models, by Mr. Edwin R. Mumford.

FEBRUARY 22. Trial of a chilled iron shield at Buckau.

New Instruments for Measuring Electric Currents and Electro-Motive Force.

A paper read before the Society of Telegraph Engineers, descriptive of the various measuring instruments suitable for the large currents employed in lighting and transmission of energy.

ENGINEERING.

JANUARY 11, 1884. The Horse-Power Expended in Electric Light Wires, by J. E. H. Gordon.

An electric sounding lead.

M. de la Croix has devised a new sounding lead which has several points of interest. It tells the exact moment of the arrival on the bottom by means of an electric alarm bell. The sounding line is in reality a cable containing two wires forming the circuit of the bell. It is attached to the ring of the lead at one end, and the hauling winch on board ship at the other. The lead consists of two parts, the lower being hung from the upper by four stems which slide in mortise grooves cut in the sides of the upper part. Its bottom is fitted with the usual hole, armed with tallow to catch a specimen of the bottom. The upper part of the lead, which hangs from the line by a hook, is a mass of lead to give due weight, but there is a hollow through its interior containing an electric contact terminating the ends of the two conductors of the cable. This contact, which is of a spring kind, is closed by a stem or plunger attached to the lower movable part of the lead. When the lead strikes bottom the plunger is driven up a hollow in the upper lead, and makes contact between the ends of the two conductors, thereby completing the circuit of the bell, which rings on board and announces that bottom has been reached.

JANUARY 18. Torpedo Boats. An article descriptive of the practice of Messrs. Yarrow & Co., of the Isle of Dogs.

Ganz's steam engine governor.

The object of the designer has been to construct a governor that can be made of any desired power for the purpose of actuating an expansion slide-valve, without necessitating heavy rotating masses.

FEBRUARY 1. The armament of torpedo boats.

The necessity of arming torpedo boats with light and efficient machine-guns has been long fully recognized, for, in consequence of the large and rapidly increasing number of this class of vessels, there is no doubt that in any future naval campaign they will be called upon to perform other duties besides that of attack on ironclads, and there will be engagements of torpedo boats with each other, and with the armed guard boats used to protect the larger fighting vessels against torpedo-boat assaults.

Such guns will also be very valuable for firing at electric search lights, for driving the gunners from the machine-guns placed in exposed situations, and for covering a retreat. For all these reasons those governments which possess navies have under consideration the development of torpedo boats into more perfect fighting machines. The principal difficulty in arming torpedo boats, especially those of the light second class, is the extra weight which a gun and an adequate quantity of ammunition entails, and the consequent loss of speed occasioned, but it would appear that the value of a gun armament outweighs to a great extent this disadvantage.

The requirements of such armament may be summed up as follows:

1. A minimum weight of armament and ammunition supply.
2. The smallest possible number of men to work the guns.
3. Sufficient power of projectile to perforate and put *hors de combat* any existing torpedo, or other similar boat.
4. Rapid fire and great facility in pointing.
5. The use of the same ammunition carried by the machine-gun armament of the larger vessels.
6. A fore-and-aft fire, and if possible an all-round fire, so as to provide equally for an attack or retreat.

One type of gun which is now being largely adopted in Continental navies for arming the first class torpedo boats is the 37 mm. Hotchkiss revolving cannon, having a total weight of 570 pounds. It can be worked by two men and fired at the rate of about sixty shots per minute. This gun, however, is considered too heavy for the second class boats, and for this class of boats the Hotchkiss Company are now manufacturing a rapid-firing single-barrel gun adapted for the same ammunition as the 37 mm. revolving cannon.

Compound engines of the S. S. Normandie.

Engines of manganese bronze.

Two sets of pumping engines for salvage purposes have just been completed by Allen & Co., in which the parts usually made of steel—that is, the piston-rod, connecting-rod, cross-head, crank-shaft, &c., with all the bolts and nuts, are of manganese bronze. These engines have been designed to prevent the loss of time which occurs in raising ships which are only partially submerged at low tide. In such cases the machinery has to remain under water for several days together, and with steel working parts great difficulty has been experienced from the journals becoming oxidized to such an extent that when the engines are started, seizing takes place and a complete overhaul has to be made, occasioning the loss of much valuable time. Great difficulty was first experienced in obtaining a suitable metal to form the bearings for the forged bronze to work in. The alloy finally used for this purpose is a hard mixture, which runs at high speeds without heating, and wears in a short time to a smooth and glassy surface. The strength of the forged bronze is about that of mild steel (29 to 30 tons per sq. in.); so nothing is lost by the adoption of the new metal.

February 8. Electric ship-signal lights.

February 15. Amsler planimeter with Halpin's locking gear.

A locking apparatus invented by Mr. Halpin, by which, when the pointer has been moved all around the figure under measurement, the index wheel may be fixed sufficiently firm to allow of the instrument being lifted and carried to a favorable situation for reading the vernier.

The Gardner machine-guns.

A description with illustrations of the single, double, and five-barrel Gardner machine-guns. Referring to the trial held at Shoeburyness in 1881, the five-barrel guns fired 16,754 rounds with only 24 jams, and in rapid firing reached a maximum of 330 shots in 30 seconds. The two-barrel gun fired 6929 rounds without any jam; the last 3000 being in 11 minutes 39 seconds, without any cleaning or oiling.

ASSOCIATION PARISIENNE DES PROPRIÉTAIRES D'APPAREILS À VAPEUR.

VIIème Congrès des Ingénieurs en Chef, 1882.

Questions discussed: On the employment of sheet steel. Notes on a peculiar brittle condition of iron and steel. Propositions relative to the test of materials employed in the construction of boilers. Accidents caused by the oily water in steam boilers. Damage to boilers from floating calcareous substances in feed water.

JOURNAL DE LA FLOTTE.

FEBRUARY 3, 1884. Description of the steamer Stanley built by Yarrow & Co. for the International Association.

FEBRUARY 10. A new lifeboat designed by Mr. Carlo Belvas.

JOURNAL OF THE FRANKLIN INSTITUTE.

APRIL, 1884. Initial Condensation of Steam Cylinders, by Prof. Wm. D. Marks.

The economy of the compound engine.

The International Electrical Exhibition.

Under the auspices of the Franklin Institute, an international electrical exhibition is to be held in Philadelphia during the autumn of this year. A suitable site has been obtained, and the exhibition building, now in the process of erection, will be finished by the middle of June. The meeting of the American Association for the Advancement of Science, which will be held this year in Philadelphia, and the expected presence of many representatives of the British Association, which will meet this year in Montreal, will attract a numerous and influential scientific gathering during the time of the holding of the exhibition; and in order that so exceptional an opportunity to promote the interests of science shall not be lost, Congress has been requested to authorize the holding of a National Conference of Electricians, to convene in Philadelphia at this time.

JOURNAL OF THE MILITARY SERVICE INSTITUTION OF THE UNITED STATES.

MARCH, 1884. The Military Service Institution, by General A. S. Webb. Science in Military Life, by Colonel F. von der Goltz, of the German Army; translated by Lieut. J. J. O'Connell.

JOURNAL OF THE ROYAL UNITED SERVICE INSTITUTION, VOL. XXVII., No. 122.

Military Ballooning, by Lieut. B. Baden-Powell.

A historical view of the uses to which balloons have been put in actual warfare, the causes of success and failure in ascents; the relative advantages of captive and free balloons; the means of inflation, and the question of navigating balloons.

Magazine Rifles and Repeaters, by Lieut. Col. Fosberry, V. C.

MITTHEILUNGEN AUS DEM GEBIETE DES SEEWESENS.

VOL. XI., No. 12. Long or short projectiles. Experiments with armor plates at the Gruson establishment at Buckau. Notes on torpedo boats. References to the various late polar expeditions. M. Bisson's standing compass.

VOL. XII., Nos. 1 and. 2. Upon the importance of steam vessels in the Austro-Hungarian merchant marine. Strength of materials. Certain factors influencing the result of experiment. Gyration and change of direction of winds—an essay upon the law of storms. Calculation of rapidity and time of flight of projectiles at Krupp's. Mangan-bronze—a composition metal tougher than gun metal and non-corrodible in sea water. Ship canal through the Isthmus of Corinth. Upon the use of electricity in firing explosives. Notes upon new ships—launching, &c. Description of the new observatory at Nice. Privateering in time of war. Transmission of earthquake wave through the ocean from Java to Aspinwall during the late eruption. Light draught portable gunboats built by the French for use in China and Madagascar. Notes upon recently built vessels.

THE MECHANICAL ENGINEER.

JANUARY 12, 1884. Tightening a loose crank-pin.

Mr. Herman Winter, resident engineer of the Morgan S. S. Line, gives the following method employed in fastening loose crank-pins of the steamships Glaucus and Morgan City. These pins had been shrunk in, but the shrinkage allowance was so great that instead of holding them, it expanded the crank eyes with the result stated. It was impossible to make new pins, as the time at disposal did not permit of it. The following expedient was therefore adopted: Holes ⅞ in. diameter were drilled along the diameter of the pin, the whole depth of the eye and about one-eighth of an inch apart. The thin wall of metal between the holes was cut away, and plugs of Muntz's metal inserted and driven home by a steel drift, having the ends rounded. The effect of this is to expand the pin with great force against the crank eye, when all the holes are driven full of plugs.

The operation was entirely successful, and appears to be a much better plan than drilling holes alongside the pin, between it and the eye, and driving steel pins in, as is commonly done. This latter operation injures the crank eye irreparably for fitting a new pin to it at any time.

RIVISTA MARITTIMA.

JANUARY, 1884. Notes on the maritime invading power of France. A year amidst the ice of the Kara Sea. Depressions and anti-cyclones. The Armstrong-Rendel type of cruisers. The Chinese ironclad corvette Tchen-yuen. The Navy of the United States. The French fleet; new ships. Experiments in the United States with the Graydon system of torpedo defence.

PROCEEDINGS OF THE ROYAL ARTILLERY INSTITUTION.

DECEMBER, 1883. Foreign armor. Experiments, and Their Bearing on our own Armaments, and the Bombardment of the Forts of Alexandria, by Captain C. Orde Brown.

Ammunition for the 1-inch Nordenfelt Machine-Gun, by Captain W. P. Blandy, R. A.

Notes on the Ordnance Exhibited in the Russian National Exhibition at Moscow, by Captain J. C. Dalton, R. A.

The Transit of Venus in 1882.

Notes on Certain Rough Methods of Approximating to Latitude and Longitude Determination without Instruments, by Lieut. T. P. Battersby, R. A.

Vent Obturators, by Major G. W. Hawkins.

Containing descriptions with plates of the vent obturators in use in the English and other services.

SCHOOL OF MINES QUARTERLY.

Gases Contained in Steel. Translated by Prof. T. Egleston.

On the Writing of Chemical Equations, by F. G. Wiechman.

Mining Laws, by Edwin P. Clark.

UNITED SERVICE GAZETTE.

FEBRUARY 16, 1884. Experiments at Brest with marine gyroscope on board the ironclad Turenne, to obtain an invariable plane while the vessel was manœuvred.

These experiments show that the invariable plane is obtained free from the errors due to a compass.

ADDITIONS TO LIBRARY.

EXCHANGES.

American Geographical Society, Proceedings. Nos. 3–4.
American Institute of Mining Engineers, Transactions. Vol. XI., 1883.
American Iron and Steel Association, Bulletin. Nos. 3-11.
American Philosophical Society, Proceedings. Vol. XXI., No. 114.
American Society of Civil Engineers, Transactions. Nos. 266-271.
American Chemical Journal, Vol. V., No. 6.
Annalen der Hydrographie und Maritimen Meteorologie. Parts XII-I-II.
Association Parisienne des Propriétaires d'Appareil à Vapeur, VIIème Congrès des Ingénieurs en Chef, 1882.
Broad Arrow. No. 818.
Connecticut Academy of Arts and Sciences, Transactions. Vol. V.
Giornale di Artiglieria é Genio. January, 1884.
Institute of Mining and Mechanical Engineers, Transactions. Vol. XXXIII., No. 2.
Institute of Mechanical Engineers, Transactions. No. 4.
Institution of Civil Engineers, Proceedings. No. 2.
Journal de la Flotte. Nos. 4-11.
Journal of the Franklin Institute. April, 1884.
Journal of the Military Service Institution of the United States. Vol. V., No. 17.
Journal of the Royal United Service Institution. Vol. XXVII., No. 122.
Mittheilungen aus dem Gebiete des Seewesens. Vol. XI., Nos. 11-12. Vol. XII., No. 1.
The Mechanical Engineer. Nos. 4, 5, 6.
Norsk Tiddskrift for Sovaesen.
Reunion des Officiers, Bulletin. Nos. 1-10.
Rivista Marittima. No. 1.
Royal Artillery Institution, Proceedings. Vol. XII., Nos. 8-9.
Revue Maritime et Coloniale. January, 1884.
School of Mines Quarterly. Vol. V., Nos. 1, 2, 3.
Société des Ingénieurs Civils. Annuaire de 1884.
United Service Gazette. Nos. 2663-2671.

DONATIONS.

Annual Report, Chief of Bureau Steam Engineering, Navy Department.
From the Office of Naval Intelligence, Navy Department:
- Ordnance Notes. Nos. 321-328.
- Krupp's Steel Ordnance Works. Report by Consul Potter.

NAVAL INSTITUTE PRIZE ESSAY, 1885.

A Prize of one hundred dollars and a gold medal is offered by the Naval Institute for the best Essay presented, subject to the following rules:

1. Competition for the Prize is open to all members, Regular, Life, Honorary and Associate, and to all persons entitled to become members, provided such membership be completed before the submission of the Essay. Members whose dues are two years in arrears are not eligible to compete for the Prize until their dues are paid.

2. Each competitor to send his essay in a sealed envelope to the Secretary on or before January 1, 1885. The name of the writer shall not be given in this envelope, but instead thereof a motto. Accompanying the essay a separate sealed envelope will be sent to the Secretary, with the motto on the outside and writer's name and motto inside. This envelope is not to be opened until after the decision of the Judges.

3. The Judges to be three gentlemen of eminent professional attainments (to be selected by the Executive Committee), who will be requested to designate the essay, if any, worthy of the Prize, and, also, those deserving honorable mention, in the order of their merit.

4. The successful essay to be published in the Proceedings of the Institute, and the essays of other competitors, receiving honorable mention, to be published also, at the discretion of the Executive Committee.

5. Any essay not having received honorable mention, to be published only with the consent of the author.

6. The subject for the Prize Essay is, "*Inducements for retaining trained seamen in the Navy, and best system of rewards for long and faithful service.*"

7. The Essay is limited to forty-eight printed pages of the "Proceedings of the Institute."

8. The successful competitor will be made a Life Member of the Institute.

9. In the event of the Prize being awarded to the winner of a previous year, a gold clasp, suitably engraved, will be given in lieu of a gold medal.

CHAS. M. THOMAS,
Secretary.

ANNAPOLIS, MD., *April* 3, 1884.

THE ESTABLISHMENT OF STEEL GUN-FACTORIES IN THE UNITED STATES.

By Lieutenant W. H. Jaques, U. S. N.,
Member of the Gun Foundry Board.

Vol. X., No. 4,—Whole No. 31, Proceedings of the Naval Institute, will be wholly devoted to an article by Lieutenant W. H. Jaques, U. S. N., on the Establishment of Steel Gun-Factories in the United States. The number will thus be a complete work in itself, fully illustrated, and will possess peculiar interest at the present time, the subject being one of paramount importance.

It is expected that No. 31, Proceedings of the Naval Institute, will be ready for issue early in May.

Orders should be sent to the Secretary, U. S. Naval Institute, Annapolis, Md.

Paper Covered, $2.00. Bound in Cloth, $2.25.

This Paper will present the report of the Board selected for the purpose of reporting to Congress what method should be adopted for the manufacture of heavy ordnance suited to modern warfare, for the use of the Army and Navy of the United States; it will contain the discussion in the XLVII. Congress, which led to the constitution of said board; the opinions of leading artillerists and steelmakers upon the subject of providing modern ordnance, and the following, relating to steel manufacture and gun fabrication:

England.

Sources from which the armament is supplied — Royal Arsenal of Woolwich — Elswick — Armstrong guns — Hydraulic machinery — Steel furnaces —Gun tools —Steam hammers — Steel manufacturers —Vavasseur gun-carriages — Sir Joseph Whitworth's Works — Hydraulic casting — Hydraulic forging — Examples of Whitworth steel — Methods of manufacturing compound armor — Bessemer Works — Basic process — Present condition of artillery — Vavasseur gun — Gun construction — Wire construction.

France.

Sources from which the armament is supplied — Bourges — Ruelle — Trucks for transportation of heavy guns — Steel manufacturers — St. Chamond — Le Creusot — Tempering pits — Steam hammers — Heating furnaces — Terre Noire — Steel and compound armor — Present condition of artillery — Gun construction — de Bauge system — Dard system — Wire construction — Schultz system — Hotchkiss revolving cannon — Hotchkiss rapid-firing gun.

Germany.

Sources from which the armament is supplied — Spandau — Krupp's Works — Krupp system — Trucks for transportation of heavy guns — Power of the Krupp guns — Present condition of artillery — Gun construction.

Russia.

Sources from which the armament is supplied — Kama — Russian Artillery gun-factory — Aboukhoff Works — Steel manufacture — Present condition of artillery — Gun construction — Steel lining-tubes.

United States.

Sources from which the armament was supplied — Sources from which the armament is supplied — Condition of steel manufacture — Cambria Iron Company — Midvale Steel Company — Springfield Iron Company.

In General.

Machines and tools for steel plant — Machines and tools for gun-factory — Buildings — Gun tool-makers — Weight of gun forgings — Plans and descriptions of sites selected by the Gun Foundry Board for gun-factories — Estimates of cost of steel plant and gun-factories.

Vol. X., No. 4. 1884. Whole No. 31.

PROCEEDINGS

OF THE

UNITED STATES

NAVAL INSTITUTE.

VOLUME X.

THE ESTABLISHMENT OF STEEL GUN FACTORIES IN THE UNITED STATES.

BY

Lieutenant W. H. JAQUES, U. S. N.

PUBLISHED QUARTERLY BY THE INSTITUTE.

ANNAPOLIS, MD.

PRESS OF ISAAC FRIEDENWALD,
BALTIMORE, MD.

PREFACE.

In offering the following pages, it has been my aim to show the necessity for the establishment of steel gun factories in the United States; to extend the information collected, and the conclusions reached, by the Gun Foundry Board; and to provide a book of easy reference to the details of the manufacture of modern ordnance.

In thanking all who have assisted me in the preparation of this work, I wish especially to acknowledge the benefit of my association with Rear-Admiral Edward Simpson, U. S. Navy, and the other members of the Gun Foundry Board.

In addition to those authorities cited by name, as well as by the establishments with which they are connected, I desire to thank

Brig-General S. V. Benét, Chief of Ordnance, War Department,

Captain Montgomery Sicard, Chief of Ordnance, Navy Department,

Mr. James M. Swank, Secretary of the American Iron and Steel Association,

Lieut-Commander F. E. Chadwick, U. S. Navy, Naval Attaché, London, England,

Lieutenant John H. Moore, U. S. Navy, and the

Office of Intelligence and Naval Library, Navy Department.

W. H. JAQUES.

NEWARK, N. J., *May* 5, 1884

THE PROCEEDINGS

OF THE

UNITED STATES NAVAL INSTITUTE.

Vol. X., No. 4. 1884. Whole No. 31.

NAVAL INSTITUTE, ANNAPOLIS, MD.

JUNE, 1884.

THE ESTABLISHMENT OF STEEL GUN FACTORIES IN THE UNITED STATES.

BY LIEUTENANT W. H. JAQUES, U. S. N.

I.

INTRODUCTION.

" Before the introduction of rifled cannon, and the use of steel as the material for their construction, the United States boasted of her Dahlgren and Rodman cast-iron guns, which were the models for imitation and the standards for comparison of all nations.

While the rest of the world has advanced with the progress of the age, the artillery of the United States has made no step forwards. Its present condition of inferiority is only the natural result of such want of action.*"

Lieutenant-Commander F. M. Barber, in a recent paper presented to the Senate Naval Committee, and prepared in view of the discussion on the construction of steel vessels, gave the following facts, which bear directly upon the very important question of providing modern ordnance:

* Gun Foundry Board Report.

At the beginning of the war, the only efficient portion of this Navy was that propelled by steam. This force was small, but most of it at the time of its construction (1855 to 1858) compared favorably with individual ships in foreign navies. Especially was this the case with vessels like the Colorado, Roanoke, and Wabash. Wherever they appeared, when first built, they excited the wonder and admiration of foreign naval authorities. No vessels had ever appeared that carried such heavy batteries, had such clear decks, and were at the same time so efficient under sail or steam.

In the day of these vessels the United States led the world in the architecture of its wooden ships, with their enormous battery power of shell-guns, as easily as it did in 1812, when its 32-pounders proved more than a match for the English 18s and 24s.

Never in the history of maritime war has any period been so fruitful in revolutionary inventions as the four years of our rebellion. It produced the monitor, the steam blockade-runner, the inclined casemate, the double-ender, the XV.-inch gun with its mammoth powder, and it developed beyond all former anticipation the wonderfully destructive power of the torpedo. Of all these inventions, the blockade-runner is the only one not purely American, and of the remainder (excepting the double-ender) it is hard to say which has received the greatest attention from foreign nations.

At the same time that they developed their broadside ironclads, they did not neglect the American ideas. The Monitor has developed into the Inflexible and Italia. The XV.-inch smoothbore had reached its zenith with us because it was cast-iron; but its size was emulated and exceeded in Europe in rifled steel, while its mammoth powder, with its secret of low initial pressures, was retained and has produced the 100-ton guns of the Duilio and Lepanto. The torpedo has developed into an innumerable variety of forms, and is now seen perfected in the Whitehead, Swartzkopf and Lay, of which, foreign nations possess thousands; to say nothing of the torpedo-boat, the most wonderful combination of speed, lightness, and handiness that is now afloat, and of which Europe possesses hundreds.

In all these years we have done almost nothing in these fields.

This may perhaps be warranted in a slight degree by our peaceful attitude and our geographical position; but we have also neglected to keep pace with foreigners in the construction of the ordinary sea-cruisers for commerce-protection.

In 1861, England commenced the construction of sea-going armor-clads wholly of iron, and all European nations have followed her. While in Europe they have gone deeply into the subject of breech-loading rifled ordnance, with tremendous penetrating power, we have idled along, trying to brace up our antiquated smoothbores by inserting a rifle-tube; and whereas they have endeavored in every possible way to mount their guns so as to obtain an all-round fire from the ship and as great a lateral train as possible for each individual gun, in our Navy we have not a single sea-going vessel that has stern-fire; and the bow-fire is in most cases very inefficient, while the train on the broadside is exceedingly limited.

If our peaceful country is ever to be involved in a foreign war, sea-going ironclads will be a positive necessity, and we are utterly unable to-day either to roll their armor-plates or to manufacture the monstrous guns that they will require.

The difficulty that we are experiencing in regard to the manufacture of such small guns as are required for our new cruisers should be a warning of the numerous obstacles that will lie in our path when those of larger calibre are required.

The spur of competition among the manufacturers of all the nations of Europe, but particularly those of England, France, Italy, and Germany, assisted by a bountiful government patronage, has produced results in the perfection of the means of waging maritime war that are positively startling. Much has been said about the ingenuity of our manufacturers supplying everything needful when called upon; but a glance at the navy lists of the world in 1882, as taken from Mr. Bowles' pamphlet on "Our New Cruisers," should convince the most skeptical that ingenuity could not compete with the scientific experience that has produced, and is producing, such vessels as these, especially when our manufacturers, from whom the ingenuity is expected, have never had the slightest pecuniary inducement to turn their attention to the required direction.

How much more difficult would it be for home ingenuity to compete with the immense plants that have been developed by long years of valuable experience, and at an immense expenditure, for the manufacture of such ordnance as modern warfare demands! Though nature has, in part, protected our coasts against possible attacks from the enormous vessels that have been put afloat abroad, and although our immense resources may afford some moral protection, neither our resources nor wonderful inventive genius will avail against the practical results of *time and experience*—elements most necessary in successful gunmaking.

Volumes could be filled with the prayers that artillerists and the advocates of providing adequate means of defence have made during the twenty years that the United States has made no advance in artillery, but in offering the report of the Gun Foundry Board for the consideration of the Naval Institute, it has been deemed best to begin with the discussion in the XLVII. Congress, a discussion that resulted in the selection of a board of officers, who were to collect such information and approve such systems as would assist Congress in deciding upon the method and means of providing heavy ordnance adapted to modern warfare. A complete history will thus be presented of the varied views held by those who have the power to provide, by their action in Congress, a proper means of defence; by those who have been trusted with the conduct of the Departments, and by those who have made the subject of ordnance more or less a life-study.

As the Board has been governed by *history*, at home and abroad, the introduction of these opinions is most important, that the Institute may, by its familiarity with the interests that governed the different representatives in their discussion, be better able to accept the opinions and conclusions of the Board.

It has been the intention of the compiler of these pages to present so thoroughly the views of all connected with the question of providing adequate armament, that the reader will have before him the important information which governed the Board in its decisions. He will thus be saved the labor of search, and, it is hoped, will also find new and useful information regarding the manufacture of gun-steel and the fabrication of modern cannon.

It is to be regretted that personal interests have entered so largely into the discussion of a question of such magnitude; but the victory will be all the greater if, under such circumstances, the *best* system shall be adopted.

In the consideration of the Fortifications Appropriation Bill, the Hon. Anson G. McCook, of New York, protested against the neglect of the Congress of the United States in leaving the fortifications in their present helpless condition:

On more than one occasion I have tried to show to the House of Representatives that the fortifications of this country are in an absolutely worthless condition for all purposes of warfare. In the last session of Congress, when this bill was before the Committee of the Whole, I offered an amendment to increase very materially the appropriation, for the purpose not only of repairing the present fortifications but of adding to them. I cited the report of eminent engineers in justification of that action on my part. . . . . I rise for the purpose of again protesting against the neglect that the House of Representatives or the Congress of the United States indulges in, in leaving our sea-coast fortifications in their present helpless condition.

It is recognized by all of us that practically we have no navy. It is asserted by the Engineer Department of the United States that for all purposes of defence our fortifications are in a worthless condition. And were it not for the efficiency of our torpedo system, in the event of war with one of the great maritime powers, the harbor of New York is as defenceless to-day as if there were not an earthwork there.

I hope the time is not very far distant when the Committee on Appropriations of this House will recognize that fact; and that the opinion of educated officers who have made the state of the fortifications of this country and of our harbor defences a life-study, will be consulted, rather than the economy which amounts to parsimony. And as one of the Representatives from the city of New York, I again, for the fifth or sixth time, and for the last time, call the

attention of the House to the condition of the harbor of that great city, and assert, on the statement of competent engineers, that it is absolutely defenceless to-day in the event of war with one of the great maritime powers of the earth.

Senator John A. Logan, of Illinois, pointed out the fact that this country cannot produce the required gun-steel:

We provide in the bill for the manufacture and fabrication of two steel guns and for the making of projectiles, powder, &c. It is a well-established fact that in this country we can not produce the character of steel that is absolutely necessary for the manufacture of guns. That article has to be purchased from abroad, and so it is with many of the things connected with the Ordnance Department.

During the consideration of the Naval Appropriation Bill, the provisions for the armament of the new steel cruisers, and the recommendations for the armament of the monitors, called forth a discussion that contained unjust criticism of a bureau whose action was necessarily restricted by the meagre appropriation that Congress felt justified in limiting. Senator McPherson, of New Jersey, recognized the true reason—"*the want of a sufficient appropriation*"—that has prevented the United States from possessing suitable armaments for her fortifications and ships and has kept the Ordnance Bureaus from making those experiments, and acquiring such information as would assist them in the selection and purchase of the *best* modern war material.

Great injustice was also done officers, who have more knowledge of the fabrication of steel cannon than any private gun-factor in the United States.

There are European powers, well advanced in the development of artillery, that have gladly accepted the opinions of American ordnance officers who have devoted their energies to the study of this great question; and we find to-day that material (*steel*) employed, and that system of gunmaking adopted by England and France, and imitated by Germany, which were accepted and advocated by an American naval officer thirteen years ago.

We find also a recent publication on the "Development of Armor for Naval Use," eagerly sought for in order to obtain information on this very important and interesting subject, and pronounced by some of the leading artillerists and armor manufacturers the ablest work of its kind ever published. This history of armor development and trials was prepared by an officer of the Navy, who for

years was associated with that Ordnance Bureau whose action has been so severely criticized.

The Institute may well be proud that its rolls contain the names of such professionally distinguished men.

The Hon. W. C. Whitthorne, of Tennessee, called attention to the lamentable weakness of the Navy, and gave his opinion of what ought to be done:

Mr. Chairman: Having been for a number of years a member of the Naval Committee of this House, and during those years having given much thought and labor and study to the naval administration of the Government, although not now connected with any committee of this House having charge of that matter, yet from mere force of habit, if from no other consideration, I take very great interest in every proposition which affects that administration.

Before proceeding to notice the terms of the bill, I may be permitted to ask the attention of the committee to what is the real condition of the United States Navy. I content myself now with the simple answer that at present its condition is one of lamentable weakness and inefficiency. The special weakness of the American Navy is this: First, we have no guns; in the second place, we have no vessels of any speed; in the third place, we have no armored vessels fit to cope with the weakest naval power known to the history of the world. None of our vessels could withstand an attack from any one of the naval powers. Peace now prevails. I for one trust that it shall always be the inheritance of our people. But yet the careful student of the struggles of mankind must know that peace is not the constant inheritance of any people; hence we should be ready for defence. Besides, we owe something to our commerce. We owe something to the protection of our coasts. What shall be done?

It is, in my judgment, that of liberal expenditures in the way of experiments. We need speed; we need guns and we need armor. Shall we build a large number of vessels at once in order to get these things? In my judgment, no. Practical common sense would say, make your experiments first to illustrate the question of speed. Make your experiments first and build your guns in your own factories.

The Hon. G. M. Robeson, of New Jersey, added:

With regard to guns, let me say just this: That we appropriated $100,000 last year for the purpose of experimenting or entering upon a course of experiments for casting certain trial guns. We should have appropriated an additional amount this year, but we have a communication from the Bureau of Ordnance which says that they have applied to all of the firms of this country that can produce the steel and that they are at work producing it; but they have not yet finished it, and as a consequence they have not been able to expend more than $65,000 of that appropriation.

Extract from the report of the House Naval Committee:

It is not in ships alone that we are weak. The guns on the single-turreted monitors are all smoothbore muzzle-loaders. It is manifest that our navy is sadly deficient in guns, and that we have not one high-power, long-range, rifled breech-loading cannon afloat in the Navy; and it may as well be said here that we have not one to put afloat.

It is perhaps not to be regretted that we have not spent large sums of money in the manufacture of guns since the close of the war, for we have doubtless escaped many expensive blunders thereby. The time has not been wholly lost. Our manufactures have been developed during that period to a degree quite unprecedented in our own history. At the close of our war there was not a pound of steel made in this country fit for the fabrication of cannon. To-day our manufacturers can produce steel of the best quality for that purpose in very large quantities, and with their present plant can supply over 150,000 tons a year for that purpose, besides supplying the present demand for steel for all other purposes. The steel made in this country is better than that made in Europe. In six months' time, if we were called upon for it, we could furnish all the steel which the gunmakers of the world could use.

To compare our Navy with the navies of other countries may be humiliating, but it will prove useful and result to our advantage.

We here take leave of this branch of the subject with no further comment; argument would seem to be quite out of place.

The above plainly shows the need of modern ordnance, but it conveys a false impression of the capabilities of our steel manufacturers to produce the proper material for said ordnance, and makes no reference whatever to the total lack of any *factory* for the fabrication of heavy *steel* guns.

The development of steel manufacture for other than ordnance purposes in the United States has indeed been remarkable; and had there been a sufficiently large demand for guns, there is no doubt a few of our steel manufacturers would have increased their plants in order to meet it; but, whatever their experience and casting capacity, they have no means of forging, and consequently cannot supply the requisite material.

The House of Representatives having under consideration the Naval Appropriation Bill, the Hon. B. W. Harris of Massachusetts said:

Mr. Chairman:—After a service of nearly ten years as a member of this House, and a service of nearly eight years as a member of the Committee on Naval Affairs, I had hoped now, in the closing session of this Congress and during the few remaining days of my Congressional life, to be able to secure the passage of some of the measures reported by my committee, and some of the fruits of earnest and honest effort which I have made for the building up and

improving of the American Navy. . . . . Not only are we deficient in ships, but we are unable properly to arm those we have.

The Secretary of the Navy in his late report to Congress has put in official form a statement of the number and character of the guns now on hand adapted for naval use. It is as follows:

ORDNANCE.

The guns of the Navy are 2233 smoothbore, muzzle-loading cannon of various calibers; 77 Parrott muzzle-loading, 40-pounder rifles; 267 similar 80-pounder rifles; 51 muzzle-loading, 180-pounder converted rifles; 26 breech-loading, 40-pounder converted rifles; and 10 breech-loading, 80-pounder converted rifles.

The eighty-seven converted rifles have fair power and may be considered useful for the present. The Parrott rifles were made during and immediately after the rebellion; they might in an emergency serve a subordinate purpose as part of our armament, but are in no real sense suited to the needs of the present day. The smoothbore guns are incapable of contending with rifled guns throwing one-half their weight of shot.

With not one modern high-powered cannon in the Navy, and with only eighty-seven guns worth retaining, the importance of action for the procurement of naval ordnance seems apparent, if the Navy is to longer survive.

Our total naval force afloat is thirty-eight cruising vessels of an inferior character, all of which must soon become unfit for naval purposes; and for harbor and coast defence we have fourteen single-turreted ironclads, armed with smoothbore guns of an antiquated type; and, according to the Secretary of the Navy, "only eighty-seven guns worth retaining." This is a spectacle demanding the serious attention of Congress and the people. The remedy is in the hands of Congress. It has been warned by every Secretary of the true condition and the pressing needs of the Navy at almost every session for the past ten years at least.

I cannot believe that the people of this great country, if they could directly express their will, would endorse such a policy or permit its continuance. . . . .

Now, Mr. Chairman, of what use is it for this House of Congress to do anything more in respect to building ships unless at the same time we do something for guns? You may build a ship perhaps in two years. You can not arm it with the means we have in this country to-day in the same time. Why not make provision for guns at the same time you begin the construction of the ships?

But, Mr. Chairman, what does this bill appropriate for ordnance? One hundred thousand dollars for ordnance for the Navy. What does it mean? It means that the Ordnance Department of the Navy wants $100,000 to experiment with, and is not ready to tell Congress what sort of guns the service requires.

But what is being done, Mr. Chairman? I understand that five 6-inch guns are being constructed in the Washington navy-yard on the appropriation of $100,000 of last year. That is being done for the purpose of finding out what kind of a gun to build.

England has armed herself with the Armstrong and other guns, and the nations of Europe have armed themselves with the Krupp gun, while the American vessels have no guns worthy the name.

HON. FRANK HISCOCK, of New York. I desire to ask the gentleman a single question in reference to that. My understanding in reference to that appropriation of $100,000 made last year is that it has not been expended, on account of the difficulty of getting metal. Now, I should like to hear from the gentleman from Massachusetts on that point.

HON. B. W. HARRIS, of Massachusetts. Mr. Chairman: The American manufacturers of steel only desire to have an opportunity given to them to furnish all the steel which may be required for the American Navy. And they can do it at short notice. The evidence is before us, Mr. Chairman, that these American manufacturers can furnish as good steel as can be found anywhere in the world. There is no trouble about it. We want guns, and there are men outside of the Ordnance Bureau who have already learned the trade and art of making them. I think the time has come when Congress should say to the Navy Department, "We must have guns, and here is the money with which to provide them."

Mr. Chairman, there are only two great gun manufacturers in the United States. One is at South Boston and the other at West Point, New York. These establishments have made nearly all the guns, both for the Army and the Navy, for the past fifty years or more. They have served the country well and have never failed it in time of need. These foundries have been standing almost idle since the close of the war for want of patronage. The one at South Boston, now almost idle, has a plant of nearly $1,000,000 in value. It has kept its works in order at great cost and at great loss, hoping again to be able to serve the Government. If the Navy wants guns of cast-iron in whole or in part they can be made there. If cast-steel guns would better serve the purpose, as some believe, they could soon be produced there. If guns of wrought-iron or steel are required they cannot now be made there or elsewhere in this country. But these companies would gladly undertake to prepare their works with such aid as the Government alone is able to furnish for the construction of wrought-steel guns of the largest sizes required for the service.

These two companies in January last came to the War Department and offered to combine their establishments and all their capital, experience, and ability under one management, and prepare themselves to make steel wrought guns and to put the whole at the disposal of the Government if it would assist in the construction of a steam-hammer of the required size. Their offer met with favor and approval, as the following correspondence shows:

THE SECRETARY OF WAR.

L. R., No. 22.] ORDNANCE OFFICE, WAR DEPARTMENT,

Washington, January 16, 1882.

SIR: I have the honor to enclose a letter from the President of the South Boston Iron Company, of January, 1882, requesting assistance in his efforts to "obtain proper government aid to enable me (him) to construct and complete a creditable ordnance manufactory in this country," and giving his reasons therefor.

It is a well-known fact that the proper facilities for heavy-gun constructions on modern types are not to be found in this country. The plant and mechanical experience are confined mainly to the casting and finishing of simple cast-

iron guns. The preparation and manipulation of steel in large masses suitable for heavy ordnance are beyond the resources of our private foundries. But steel in some form must enter into the construction of guns, and constitute a part, if not all, of the gun itself. At present, all such steel has to be procured abroad, and is not always of the required quality.

Recently, the breech-receivers for the 12-inch rifles, under contract, were rejected, the steel not being up to the standard.

Constant and careful official supervision on the part of the government is essential to the attainment of uniform and reliable results in the production of any metal for gun construction, and particularly so with a metal so subject to variation as steel; but such supervision is only practicable in the foundries of this country. That we should not depend on foreign workshops for this indispensable material, but depend on home enterprise, is in accordance with the spirit of the laws.

The advantage of using steel exclusively in gun construction is apparent when European authorities claim that an all-steel gun, having a thickness of walls of one caliber, possesses greater strength than a cast-iron gun hooped and tubed with steel, having much thicker walls. This advantage over simple cast-iron is still more signal, as it admits of the production of a much lighter steel gun with superior power for the same diameter of bore. In the commencement of its manufacture, it would not perhaps be practicable to produce steel of a suitable quality in larger masses than are required for hoops or light tubes, such as are employed in France, Italy, and other European states where cast-iron enters largely into the system of gun construction. For the production of the large ingots required in the manufacture of heavy steel guns abroad, steam-hammers are employed of 40, 60, and 100 tons weight, or hydraulic presses of thousands of tons power. Even with steel wire or steel riband guns, a system of construction that is now attracting the serious attention of artillerists in France and in England, the inner steel tube is required to be of very considerable size and weight.

There are but two ways to meet the case: First, by the establishment of a national foundry, being exclusively under governmental control; second, by assisting and fostering one or more of our private foundries, to enable them to prepare their plant, &c.

The South Boston Iron Works and the West Point Foundry are the only ones that have now any portion of the plant and experience. Both of these have made guns for the United States during the last half-century, and have always given satisfaction. All the states of Europe, with the exception, perhaps, of Russia, are dependent upon private industry for the steel employed in the manufacture of their heavy cannon; and it is more than likely due to the aid and encouragement afforded them by the government that private establishments in Europe have attained to such celebrity in the quality of their productions. I have the honor to recommend that the attention of Congress may be called to this subject, so important to the defences of the country.

The reference of this paper to the Board on Heavy Ordnance, now in session in New York, for an expression of its opinion, is deemed proper in connection with the duties devolving upon it, and is respectfully recommended.

Very respectfully, your obedient servant,

S. V. BENÉT,

Brigadier-General, Chief of Ordnance.

The Honorable THE SECRETARY OF WAR.

[First indorsement.]

Respectfully referred to Colonel George W. Getty, President of the Board on Heavy Ordnance, New York city, for an expression of the opinion of the Board upon the subject presented by the Chief of Ordnance in this communication.

By order of the Secretary of War, H. T. CROSBY, *Chief Clerk.*

WAR DEPARTMENT, *January* 18, 1882.

OFFICE OF SOUTH BOSTON IRON COMPANY,
Boston, January, 1882.

SIR: With a view to enlist your sympathy and assistance in my efforts to obtain proper government aid to enable me to construct and complete a creditable ordnance manufactory in this country, I beg to call your attention to the following facts and my resulting proposal:

The South Boston Iron Company has been actively engaged in the manufacture of ordnance for the United States Government for more than half a century. During this long period of service its record has been of the highest character, and at all times it has faithfully executed its engagements with the Government. It has added largely from time to time to its machinery and fixtures, until it is in condition to fabricate cannon of the largest caliber without delay, and until the value of its plant is more than a million dollars. I am aware, however, that such facilities as we have are entirely inadequate to the demand likely to be made for the armament of our Navy and for our coast defences.

Desiring to continue the leading position we hold in the line of our business, and believing that we have the experience and ability at command to successfully produce cannon of large caliber of iron or steel from American ores, I beg to submit the following proposal and petition:

I propose to erect blast-furnaces, steel-producing plant, steam-hammers of large size, machine-shops with facilities for finishing cannon from eighteen to a hundred tons weight at the rate of one per day, furnaces and rolling-mill for the manufacture of armor-plates, foundry for the casting of guns and projectiles, and shops for the manufacture of gun-carriages.

The details of construction to be subject to the approval of the War and Navy Departments, with right to representation on the board of direction, the United States Government to have the right to take possession of the entire property at any time, at a fair appraisal of value, and to have the right to control the use of the entire works, at such rate of compensation as shall not exceed the percentage of profit heretofore paid for similar work.

I ask the Government to furnish the means to make such additions by the issue of a 3 per cent 10-40 bond of a similar character to the bond issued to assist the construction of the Pacific Railroad.

It is believed that the requirements of the Government for such an establishment would insure our ability to meet the payment of the said bonds at maturity: and it is believed to be of the highest importance to the Government to have such an establishment available, and that it cannot be obtained except by direct purchase or by some such encouragement as proposed.

The foregoing scheme is sketched to point out the fact that the Government may obtain the war material it so much needs at a proper cost, and at the same time enlist the watchfulness of private interest to develop the results of progressive invention until the establishment should become efficient and complete to the highest degree.

Very respectfully, your obedient servant,
WM. P. HUNT, *President.*

General S. V. BENÉT, United States Army,
Chief of Ordnance, Washington, D. C.

L. R., No. 229.]

WEST POINT FOUNDRY,
Cold Spring, January 18, 1882.

SIR: Mr. Wm. P. Hunt has sent us a copy of his communication to you in regard to the establishment of a manufactory of ordnance with the aid of the Government.

As we are the only other firm engaged in the business we think proper to say that we coincide with Mr. Hunt's views, and that in our judgment there is no other way to create the necessary "plant" to manufacture such ordnance as is now required.

We would also say that having, like the South Boston Iron Company, furnished ordnance to the Government for more than fifty years, and having, we believe, the confidence of the Ordnance Department, should it be desired to furnish means to establish a manufactory we would have equal claims on the patronage of the United States.

It would probably, however, not be deemed advisable to assist two establishments, and no doubt it would be considered best to do all the work in one.

Should this be the case, we would say that we think that the interests of the West Point Foundry and the South Boston Iron Company could no doubt be consolidated on a basis which would be for their mutual advantage, thereby creating one establishment of large capacity, which would form an excellent basis on which to build up such a "plant" as is now required by the Government.

It seems to us that such an arrangement would promote the interest of the United States as well as the manufacturers, and create a suitable "plant" in as short a time as the nature of the work will admit.

Very respectfully, your obedient servants,

PAULDING, KEMBLE & CO.

General S. V. BENÉT, United States Army,
Chief of Ordnance, Washington, D. C.

[First indorsement.]

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, July 19, 1882.

Respectfully submitted to the Secretary of War in connection with my letter on the same subject, of 16th instant, transmitting a letter from the South Boston Iron Company. I respectfully recommend that this letter be referred to the Board on Heavy Ordnance, New York.

S. V. BENÉT,
Brigadier-General, Chief of Ordnance.

[Second Indorsement.]

Respectfully referred to Col. George W. Getty, President of the Board on Heavy Ordnance, New York City, in connection with previous papers submitted the 18th instant.

By order of the Secretary of War.

H. T. CROSBY,
Chief Clerk.

WAR DEPARTMENT, *January* 21, 1882.

OFFICE OF BOARD ON HEAVY ORDNANCE AND PROJECTILES,
Army Building, cor. Greene and Houston Streets,
New York City, January 24, 1882.

The ADJUTANT-GENERAL, U. S. ARMY,
Washington, D. C.:

SIR: This Board, to whom have been referred the letters of Mr. W. P. Hunt, President of the South Boston Iron Company, and of Paulding, Kemble & Co., proprietors of the West Point Foundry, to the Chief of Ordnance, asking governmental aid to enlarge the facilities of their establishments for the manufacture of large guns involving the use of steel, together with the letter of General Benét, transmitting the same with his views thereon to the Secretary of War, has the honor to present its opinion upon the subject set forth in those communications as follows:

For the past twenty years the demand for suitable naval and sea-coast armaments to meet the problem of national defence, has taxed the mechanical skill

and resources not only of the governmental authorities of the warlike powers of the Old World, but also of their leading gun manufacturing establishments. During that period, we have witnessed the advance of heavy ordnance from the 12 to the 100-ton gun, with corresponding increase in the weight of projectiles, while improvements in powder and the chambering of the more recent rifled cannon, have permitted the use of charges so largely augmented as to add nearly one-half to the initial velocities of their projectiles. Whether or not a gun satisfactory in its method of construction and in the perfection of material used has been reached, there can be no doubt that valuable experience has been gained and very marked improvements arrived at from year to year. While the large establishments at Woolwich, and at Elswick on the Tyne, have been developing a method of built-up wrought-iron cannon on the English system, the vast Essen foundries have produced a steel breech-loading rifled gun of great power and strength, which has given to Herr Krupp a world-wide reputation.

France and Italy, in the meantime, have experimented, with more or less success, largely in the use of cast-iron and steel combined, for heavy ordnance, as a cheaper method of construction.

Though we have not the information to determine absolutely what will be the final method and material of construction adopted for heavy cannon as the resultant of past experience and progressive trials, it now seems probable that steel, by reason of its superior tenacity and limit of elasticity, will be largely used in the system of built-up guns.

In view of the great demand for heavy ordnance for our sea-coast defences, involving the probable use of 2000 guns, for the most part of large caliber, and the insufficient preparation and development of the leading iron manufactories of this country for constructing heavy guns of other material than cast-iron, it seems probable that any attempt on their part to meet the national demand without government aid will result in both material and financial failure.

This Board therefore concurs with the Chief of Ordnance in his views of the question of assisting some of our leading cannon factories to enable them to commence successfully the construction of a suitable armament for our sea-coast defences.

GEORGE W. GETTY,
Brevet Major-General U. S. A., President of the Board.
Z. B. TOWER,
Colonel of Engineers, Brevet Major-General, U. S. A.
A. R. BUFFINGTON,
Lieutenant-Colonel of Ordnance.
F. H. PARKER,
Major of Ordnance.
JOHN MENDENHALL,
Major First Artillery, Brevet Colonel, U. S. A.

HON. B. W. HARRIS.—The men who make these offers know how to make guns. They have no trade to learn. They have no reputation to make. The companies which they represent have served the country faithfully and with honesty for more than half a century. They ought to receive the aid and encouragement which they ask, and they should be employed steadily in the fabrication of guns of which we are so sorely in need.

Mr. Harris was instructed by the committee on naval affairs to offer an amendment, which contained:

For the purchase or manufacture of cannon and their carriages, and for machine-guns for the armament of said cruising vessels and said dispatch vessel, in the manner above provided for, $1,161,000.

And the Secretary of the Navy is hereby authorized to contract for the purchase or manufacture of said cannon, their carriages, and machine-guns, with reputable and responsible American manufacturer or manufacturers, at the lowest bid after advertisement and competition. Said cannon shall be constructed upon such designs and of such material as shall be approved by the advisory board; and said contracts shall contain such terms and conditions as the Secretary of the Navy and said advisory board shall deem best calculated to secure prompt execution and perfect workmanship, and shall best protect the interests of the United States.

We have taken the advisory board's estimate for ships' guns, and we may say to arm these vessels authorized by that amendment will require for guns, carriages, and machine-guns $1,161,000. We put into your hands this fund, to provide us with guns. You shall do it by offering to American manufacturers of guns the opportunity to compete, and you may bind them to any conditions or contracts which will insure good workmanship.

THE HON. J. D. C. ATKINS, of Tennessee, in reply to Mr. Harris' attack upon the ordnance officers of the naval service, said:

The gentleman has spoken in a sneering manner of the $100,000 appropriated for guns in this bill; he has spoken of that in such a way as to convince this House that we have no officers, no artisans in our Navy competent to make guns.

HON. B. W. HARRIS . . . . We never had guns in our Navy made by officers of the Navy.

HON. J. D. C. ATKINS. We have no artisans competent to make guns! If that is true, we have no artisans competent to make ships. And just for that reason I have opposed his proposition in this bill. I have become persuaded and satisfied that the naval authorities are incompetent for the task which the gentleman from Massachusetts would now thrust upon them. I say I have become satisfied of their incompetency, and I am not surprised at it. I do not wonder at it. The naval authorities of the world have shown themselves incompetent. There are constant changes in gunnery and constant changes in armor. Why, it was but the other day the gentleman from Tennessee, my colleague [Mr. Whitthorne], alluded to the test which had been made at Spezzia, in Italy, with regard to armor, and it was there shown that armor had been found that was superior to projectile force. A while back, perhaps a year ago, it was understood that projectile force had the advantage of resistance; now resistance has the advantage of projectile force.

Sir, I feel that the gentleman has brought us to this conclusion, that we had better pause, we had better wait till the trials at Spezzia have been proved, and that we had better wait till some other trials shall have shown that the best gun has not yet been made; and when you have got approved patterns and models of ships and guns, then I would be prepared to meet the gentleman with liberal appropriations to increase the American Navy.

Mr. Harris modified somewhat his previous statements, and continued:

I did complain that the gunmakers of this country are not allowed to make any guns for us. I mean to say that for many years we have not offered to the

gunmakers of the country an opportunity to construct any guns; and until Congress authorizes and instructs the Secretary of the Navy to purchase or manufacture guns for the armament of the Navy we shall continue to be as helpless as we are to-day.

It is unfortunate that such incorrect impressions should be conveyed to Congress for its action upon a subject of great importance, by those so long connected with committees and departments constituted solely for the best advancement and development of their special work! Congress must largely accept the conclusions and opinions of its committees, and must depend upon them for useful and correct information by which its work will be expedited. During the Senate's discussion of the bill, some of these impressions were corrected by Mr. Hale, the representative of the Senate Naval Committee, who had capably and intelligently considered the question.

While it is most natural that Representatives should be governed by their local interests, since they are elected to further these interests, they should not be unjust to men who have been equally necessary, if not more so, to the government in its time of need. They should not represent that the country possesses a means of providing a proper armament for its fortifications and ships when it has been so emphatically proved that gun-steel of sufficient sizes cannot be produced "*at short notice*" by our own manufacturers, and that the United States has not a single factory where it can manufacture heavy *steel* guns.

The following statement of the Gun Foundry Board will assist much to correct the impression that the United States possesses "two great-gun manufacturers," who "have made nearly all the guns, both for the Army and Navy, for the past fifty years," and who are prepared to furnish the required armaments without delay:

> Previous to and during the civil war the armaments of the United States were supplied from—
>
> The Cold Spring Foundry, West Point, N. Y.
> The South Boston Iron Works, Boston, Mass.
> The Fort Pitt Foundry, Pittsburgh, Pa.
> The Reading Iron Works, Reading, Pa.
> The Builders' Iron Foundry, Providence, R. I.
> The Phœnix Iron Company, Phœnixville, Pa.
> The Ames Manufacturing Company, Chicopee, Mass.
>
> Since the termination of the war the Fort Pitt Foundry has ceased to exist. The South Boston Iron Works Company has

manufactured a few experimental guns, and, with the West Point Foundry, has executed some small orders of the Government in the conversion of cast-iron smoothbores into rifle guns by inserting and rifling a coiled wrought-iron tube.

None of the companies mentioned above have ever made steel guns, and virtually the United States is destitute of a source from which such an armament as the age demands can be supplied.

It is marvellous how such a statement—"*we never had guns in our Navy made by officers of the Navy*"—could be intelligently accepted when the prominence of the Dahlgren gun is recalled. Not only was it designed by a naval officer, but all the guns that were manufactured at the works named above were made under the supervision and inspection of army or naval officers, from designs and drawings made by them, subjected to tests prescribed by them, and made of material whose analyses were carefully indicated by them.

In the correspondence presented to Congress by the gentleman who advocated the interests of the two companies seeking government aid, the Chief of Ordnance, War Department, states emphatically, that "it is a well-known fact that the proper facilities for heavy gun constructions of modern types are not to be found in this country"; and that the "plant and mechanical experience are confined mainly to the casting and finishing of simple cast-iron guns."

Mr. Whitthorne also presented a similar statement during the discussion of the appropriation for the steel cruisers:

> We are not prepared in any of our navy-yards or in any of the workshops or manufacturing establishments of the United States to supply the guns that should be used on the steel cruisers when constructed.

The Chief of Ordnance, in his sympathy for these companies (who, perhaps, ought to be rewarded for what they have done), has given the impression that they possess sufficient plant and experience to undertake the fabrication of the guns which the country now needs; and, by the prominence of his approval, has endorsed the statement of the value of their gun-plant ($1,000,000), and its capability to "fabricate cannon of the largest caliber without delay."

The proposition, however, made by one and agreed to by the other, to erect a plant for the manufacture of steel guns, shows that this value of plant and capacity to fabricate cannon could have no connection whatever with the production of modern steel guns; in fact, that por-

tion of the plant which could in any way be made available is already the property of the Government; and, as far as experience in the manufacture of the modern steel cannon is concerned, the country has made no demand that would require such experience of them.

Further, the Board unanimously decided: *All history warns against such a partnership as is contained in their proposal and petition.*

In considering the best means of establishing steel gun factories in the United States, the question of reward for past services should be entirely put aside. It would be just as pertinent for the shipbuilders who designed and constructed our famous wooden ships, to ask government aid for the establishment of a steel ship plant, because they had "faithfully executed their engagements with the Government."

As the building of steel ships is a new art, so is the fabrication of steel guns. We must, therefore, look to those who have experience in the machining and assembling of steel parts, and must offer such inducements that steel workers will feel justified in the expenditure of the large sums necessary to develop their plants to the proper point.

The report of the Gun Foundry Board is particularly acceptable, because its opinions are the results of a careful study of the successes and failures of those nations that have expended millions of money, and passed through many years of valuable experience in order to obtain the best gun material and most effective type.

We hope its conclusions will be as readily adopted as was the amendment to the Naval Appropriation Bill, which the Hon. J. F. C. Talbott, of Maryland, offered by direction of the Committee on Naval Affairs:

> The President of the United States is hereby authorized and required to select from the Army and Navy five officers who shall constitute a board for the purpose of examining and reporting to Congress which of the navy-yards or arsenals owned by the Government has the best location and is best adapted for the establishment of a Government foundry for the manufacture of ordnance adapted to modern warfare for the use of the Army and Navy of the United States, the cost of all buildings, tools, and implements necessary to be used in the manufacture thereof, including the cost of a steam-hammer of sufficient size for the manufacture of the heaviest guns; and the President is further requested to report to Congress the finding of said board at as early a date as possible: *Provided*, That no extra compensation shall be paid the officers serving on the board hereby created.

In further consideration of the question, the Hon. Secretary of the Navy communicated the following to the Chairman of the Senate Committee on Appropriations:

NAVY DEPARTMENT,
Washington, February 5, 1883.

SIR: Herewith I have the honor to submit for the consideration of the Committee on Appropriations, a communication to me from the Chief of the Bureau of Ordnance, showing the necessity for full appropriations for the work of that bureau, and submitting his views as to the best method of securing for the Government a foundry and steam-hammer for the manufacture of heavy guns.

This subject is one of the first importance in connection with our military establishment, and I respectfully urge the committee to give it careful consideration.

Very respectfully,
WM. E. CHANDLER,
Secretary of the Navy.

HON. WM. B. ALLISON,
Chairman Committee on Appropriations, United States Senate.

BUREAU OF ORDNANCE, NAVY DEPARTMENT,
Washington City, February 3, 1883.

SIR: The naval approriation bill for the fiscal year ending June 30, 1884, having passed the House of Representatives, the following remarks are submitted upon that part of it which relates to the Bureau of Ordnance.

. . . .

An estimate of $100,000 was submitted for continuing the manufacture of steel rifled breech-loading guns with carriages and ammunition: this has been stricken out by the House, and a provision has been inserted reappropriating such part of the $100,000 given last year as may be left over at the end of the present fiscal year.

The amount thus made available will probably be about $35,000.

It is the opinion of the Bureau that the Senate should be asked to restore the original item of $100,000, for the following reasons:

As soon as a proper quality of steel can be produced and types developed, we should commence at once to procure an armament for the general service. Now, the $35,000 re-appropriated will procure only about five such guns with their carriages and ammunition; whereas, the moment we find ourselves in a condition to duplicate any good type of gun, we should wish to procure a considerable number as soon as possible, and as this may happen any time, the Bureau ought not to be without the means of immediately acting in the direction of rearmament.

The House has inserted a provision establishing a mixed board of Army and Navy officers to examine and report which of the navy yards or arsenals is best adapted for the establishment of a government foundry for the manufacture of ordnance adapted to modern warfare, with estimates of cost, etc., including a steam-hammer, for the manufacture of the heaviest guns.

The principal apprehension to be entertained with regard to such an establishment is that it might in time come to occupy very much such an attitude in regard to the development of artillery as has been occupied in England by the great government establishment at Woolwich.

It is thought to have been mainly owing to the conservative influence of Woolwich that the English so long adhered to a faulty system of gun construction, to muzzle-loading, to a bad system of rifling and rotation, and to an inferior kind of armor-piercing projectile.

The great private firm of Krupp, in Germany, and those of Armstrong, Whitworth, and Vavasseur, etc., in England, have all led Woolwich in the march of improvement, and it is mainly owing to the efforts of the first-named firm, that artillery has reached its present point of development.

With these examples before us, it would seem injudicious to proceed to the erection of a great government establishment where all the ordnance for the country should be completely made.

Now, whether the government should establish a great steel-producing foundry is another branch of the question which might be advocated affirmatively on better grounds than could be the case with the proposition for a gun-constructing establishment. On the other hand, it is apparent that many private firms have furnace capacity enough to produce large ingots, but they have small forging facilities, and the cost of a heavy hammer and cranes, etc., is so large (from $200,000 to $500,000) that they hesitate to purchase, being uncertain whether they will ever receive enough government orders to cover the cost of the plant.

This being the case, if it be determined to stimulate private enterprise, three courses seem open, two of which are virtually the same:

1st. Sufficient orders can be guaranteed to a firm to induce it to purchase a hammer and engage in production for the government.

2d. A hammer can be purchased for a firm and sufficient orders be given to enable the company to reimburse the government for the cost of the hammer by means of rebate per pound of steel delivered.

3d. Let the government purchase a hammer, and, erecting it in some steel center (say near Philadelphia), maintain it with a force sufficient to work it; let companies having heavy forgings to make on government orders send their ingots to this forge and have them hammered under *their own* direction and supervision, the government charging a reasonable amount for the use of its hammer, its fuel, the services of its workmen, and wear and tear, this sum to be deducted from the contract price of the forgings. Of course, there will be a charge against the government for transportation of forgings to and from the hammer, and this will result in the restriction of heavy government work to the firms in the vicinity of the hammer.

Of these plans the Bureau prefers the last. The first two have the defect of destroying the competition and confining the government to steel of a particular production.

The adoption of the latter plan would be no doubt expensive (in maintenance and transportation charges), and would probably confine serious competition to the neighborhood of the hammer, but the government would be in a measure independent of the companies, and if, in the future, it were deemed best to establish foundries and construction shops, the hammer could be removed to them.

I am, Sir, with high respect, your obedient servant,

MONTGOMERY SICARD,
Chief of Bureau.

HON. WILLIAM E. CHANDLER,
Secretary of the Navy.

In the following letter, copies were enclosed of the correspondence already presented by Mr. Harris (pages 541, 542):

NAVY DEPARTMENT,
Washington, February 6, 1883.

SIR: The Department sends you herewith a communication from the South Boston Iron Company and also one from the West Point Foundry, suggesting a consolidation of interests by these firms, and the erection by them of a large ordnance-producing establishment, to furnish funds for the building of which the United States shall issue bonds similar to those issued to aid in the construction of the Pacific Railroad.

The question of the manufacture of ordnance for the government by private firms has been alluded to in the Report of this Department, and is also discussed

in a report to the Department by the Chief of the Bureau of Ordnance, dated February 3, which communication has been sent to you in my letter of the 5th instant.

In the latter document the objections to concentrating the expensive plant for all ordnance work in a single private factory are stated, but as the Department considers that your committee should be in possession of the views of two of the principal firms interested, their communications are inclosed.

I have the honor to be, very respectfully,

WM. E. CHANDLER,
Secretary of the Navy.

HON. WILLIAM B. ALLISON,
Chairman Committee on Appropriations, United States Senate.

During the following discussion of the bill in the Senate, some changes were made in the text of the clause authorizing the appointment of the Gun Foundry Board:

The next amendment was, in line 191, after the word "and," to insert "one-half"; so as to read:

And one-half of any balance of the appropriation made for commencing the manufacture of steel rifled breech-loading guns with carriages and ammunition, that may be expended during the fiscal year ending 1883, is hereby re-appropriated and made available for continuing that service during the fiscal year ending June 30, 1884.

MR. ANTHONY. I ask the Senator in charge of the bill why the whole amount is not appropriated? Why is it stricken down to one-half?

MR. HALE. The committee considered that in the state of progress that the work is in, hardly anything having been expended, and much more time being required before large appropriations could be used, one-half of the amount in hand, which is nearly all of the appropriation last year, together with the $150,000 that we give now, would be all that could be expended during the year. That is the reason why it was limited to that.

MR. MCPHERSON. May I ask the Senator in charge of the bill what sum has been previously appropriated, which appropriation has lapsed, of which he intends to appropriate one-half?

MR. HALE. One hundred thousand dollars.

MR. MCPHERSON. That would then add $50,000 to this appropriation?

MR. HALE. Nearly $50,000, as very little of it has been expended.

MR. MCPHERSON. Why has it not been expended?

MR. HALE. Because these experiments are things that should be conducted carefully, with great deliberation, and the Department has not been in a condition where it could expend the money advantageously. It requires time, as the Senator will see, in making these experiments in order to decide how they can best make them. I think it has been rather meritorious on the part of the Department that they have not rushed into the matter with hot haste, but have been deliberate and cautious.

MR. MCPHERSON. There have been tests of ordnance in other countries that have proved to be successful, showing ordnance of proper quality, of proper efficiency. Is there any reason why the Department should delay the purchase of guns, which I understand are sadly needed, or is it the purpose of the committee in this bill to restrict the Department to the manufacture of ordnance here, of which we are not ready to make any?

MR. HALE. The Senator from New Jersey knows, if he has read any of the literature touching the experiments in gunnery abroad, that other powers have spent immense sums of money in experiments compared with which our expenditures are bagatelles; and that the history of the last fifteen years especially will show that of all the enormous sums of money expended large portions have brought nothing. We are not prepared to go into anything of that kind. I suppose there might be emergencies resting upon us whereby the American Congress would be impelled to make liberal and even lavish appropriations, so that the work might be at once, at great expense and loss and extravagance even, brought to something like a head. But in our condition, and with no apprehension of immediate trouble, the Department and the Bureau are very careful about purchasing where there is some question as to which is the best, or in experimenting and devising means that should lead to our manufacturing these guns. For these reasons, as I have said, they have been what the Senator may call slow, but I think it is better in this regard to make haste slowly.

MR. MCPHERSON. I admit the force of the Senator's remarks so far as the appropriations by this Government are concerned for experimental purposes, but the experiment having been tried by other nations, I see no good reasons why we should not avail ourselves of the experience of other nations, so far as guns are concerned. We last year appropriated, according to the statement of the Senator, $100,000 for ordnance. Not one dollar of that money has been expended, and we are sadly in need of the ordnance to place upon our fortifications and upon our naval vessels. An additional sum of $150,000 is now appropriated in this bill, to which it is the purpose of the committee to add one-half of the lapsed appropriation, making $200,000. Next year I suppose the committee will report to the Senate that the $200,000, or a portion of it, has been expended in experiments, when instead of availing ourselves of the experiments of others, which according to his statement have been very costly, which they have made and which have shown conclusively that they are perfect things, it is not the purpose of this Government to avail itself of that experience or that knowledge.

Upon this question I am very much of the opinion that the trouble is from the want of a sufficient appropriation, and I do not know that it is wise to make it, to establish a plant to do all the work and go to all the expense necessary to establish it and make it efficient. I do not know but that the best plan to pursue would be to buy our ordnance abroad, or wherever we could get it, inasmuch as we need it as sadly as we do now.

The PRESIDENT *pro tempore*. The question is on agreeing to the amendment of the Committee on Appropriations.

The amendment was agreed to.

The next amendment was, in line 206, before the word "officers," to strike out "five" and insert "six"; in line 210, after the word "foundry," to insert "or what other method, if any, should be adopted"; and in line 211, to strike out "ordnance," and insert "heavy ordnance"; so as to make the clause read:

That the President of the United States is hereby authorized and requested to select from the Army and Navy six officers, who shall constitute a board for the purpose of examining and reporting to Congress which of the navy-yards or arsenals owned by the Government has the best location and is best adapted for the establishment of a Government foundry, or what other method, if any, should be adopted for the manufacture of heavy ordnance adapted to modern warfare, for the use of the Army and Navy of the United States, the cost of all buildings, tools, and implements necessary to be used in the manufacture thereof, including the cost of a steam-hammer of sufficient size for the manufacture of the heaviest guns; and that the President is further requested to report to Congress the finding of said board at as early a date as possible; *Provided*, That no extra compensation shall be paid the officers serving on the board hereby created.

The amendment was agreed to.

Mr. Logan. In the first place, it was argued some few years ago that if armor over twelve inches thick were put upon a vessel, the vessel could not plow the seas. It has been discovered since that the gentlemen who said that did not understand what they were talking about. We cannot build a vessel merely for the purpose of having it so that it cannot be penetrated, but we ought to have a vessel with a gun on it that can penetrate some other vessel. In other words, we must not always be preparing to put ourselves in such a condition that we cannot be hurt at all, but we must put ourselves in such a condition that we can hurt somebody else. That is the true theory, in my judgment; and if we have the right character of gun upon a vessel that has eight or ten or twelve inches of armor, she is a good war vessel. That is the point you want, the gun, and not particularly the thickness of the armor of the vessel, so that you have it up to a certain point, as to have your machinery covered, for instance.

Mr. McPherson. I quite agree with the Senator from Illinois that guns have gone in their destructive power far beyond the resisting power of vessels. I also agree with him that what we need are heavy guns.

Mr. Hale. On page 10, line 215, after "steam-hammer," I move to add "or apparatus"; so as to read:

Including the cost of a steam-hammer or apparatus of sufficient size for the manufacture of the heaviest guns.

The amendment was agreed to.

The report of the committee of conference having been accepted, and the bill passed, the clause authorizing the constitution of a board to report what method should be adopted to provide heavy ordnance adapted to modern warfare, stood as follows:

That the President of the United States is hereby authorized and requested to select from the Army and Navy six officers, who shall constitute a board for

the purpose of examining and reporting to Congress which of the navy-yards or arsenals owned by the Government has the best location and is best adapted for the establishment of a Government foundry ; or what other method, if any, should be adopted for the manufacture of heavy ordnance adapted to modern warfare, for the use of the Army and Navy of the United States ; the cost of all buildings, tools, and implements necessary to be used in the manufacture thereof, including the cost of a steam-hammer or apparatus of sufficient size for the manufacture of the heaviest guns ; and that the President is further requested to report to Congress the finding of said board at as early a date as possible : *Provided*, That no extra compensation shall be paid the officers serving on the board hereby created.

On the second of April, 1883, the President issued the following order:

EXECUTIVE MANSION,
Washington, April 2, 1883.

Under the provisions of section one of the "Act making appropriations for the naval service for the fiscal year ending June thirtieth, eighteen hundred and eighty-four, and for other purposes," approved March 3, 1883, the following named officers of the Army and Navy will constitute a board for the purpose of examining and reporting to Congress which of the navy-yards or arsenals owned by the Government has the best location and is best adapted for the establishment of a Government foundry, or what other method, if any, should be adopted for the manufacture of heavy ordnance adapted to modern warfare, for the use of the Army and Navy of the United States, the cost of all buildings, tools and implements necessary to be used in the manufacture thereof, including the cost of a steam-hammer or apparatus of sufficient size for the manufacture of the heaviest guns :

Commodore EDWARD SIMPSON, U. S. Navy.
Captain EDMUND O. MATTHEWS, U. S. Navy.
Colonel THOMAS G. BAYLOR, Ordnance Department, U. S. Army.
Lieutenant Colonel HENRY L. ABBOT, Engineer Corps, U. S. Army.
Major SAMUEL S. ELDER, 2d Artillery, U. S. Army.
Lieutenant WILLIAM H. JAQUES, U. S. Navy.

CHESTER A. ARTHUR.

In pursuance of the above order, the Board met in Philadelphia, Pa., April 10, and organized, with Commodore Edward Simpson, U. S. N., President, and Lieutenant William H. Jaques, U. S. N., Secretary.

From this date the Board was actively employed at home and abroad, seeking such information as would satisfactorily reply to the Act of Congress. On February 16, 1884, the Board presented its report:

GUN FOUNDRY BOARD,
1727 *Pine Street, Philadelphia, Pa., February* 16, 1884.

To the President:

In accordance with your instructions of April 2d, 1883, issued under the provision of section 1 of the "Act making appropriations for the

naval service for the fiscal year ending June 30th, 1884, and for other purposes," approved March 3, 1883, the Board composed of six officers selected from the Army and Navy, "for the purpose of examining and reporting to Congress which of the navy yards or arsenals owned by the Government has the best location and is best adapted for the establishment of a Government foundry, or what other method, if any, should be adopted for the manufacture of heavy ordnance adapted to modern warfare, for the use of the Army and Navy of the United States, the cost of all buildings, tools, and implements necessary to be used in the manufacture thereof, including the cost of a steam-hammer or apparatus of sufficient size for the manufacture of the heaviest guns," has the honor to submit herewith its report and the record of its proceedings.

In order to reply satisfactorily to the Act of Congress, it was necessary for the Board to seek information in Europe, and visits were made to England, France, and Russia. It is appropriate to state that your Board was received by both Government officials and by private companies with much cordiality, and every assistance was rendered in its investigations in those countries.

It was the desire of the Board also to visit the large German steel works at Essen, but the permission to do so, which was requested of Mr. Fried. Krupp, was not granted for reasons that will be found stated in the copy of correspondence attached to this report.

The Board, having completed its duties, has adjourned *sine die*.

Very respectfully, for the Board,

E. SIMPSON,

Rear-Admiral United States Navy, President of the Board.

Report of the Gun Foundry Board.

"The act of Congress, approved March 3, 1883, under which the Gun Foundry Board was organized, calls for a report on the following points:

1st. Which of the navy-yards or arsenals owned by the Government has the best location, and is best adapted for the establishment of a Government foundry.

2d. What other method, if any, should be adopted for the manufacture of heavy ordnance adapted to modern warfare, for the use of the Army and Navy of the United States.

3. The cost of all buildings, tools, and implements necessary to be used in the manufacture thereof, including the cost of a steam-hammer or apparatus of sufficient size for the manufacture of the heaviest guns.

The first question presupposes the establishment of a Government Gun Foundry, properly so called, the establishment to be under the absolute control of the Government, and the

details of all work to be supervised and directed by Government officers.

The answer to this question involves simply an expression of opinion as to the superior adaptability, for the purposes of a gun foundry, of any navy yard or arsenal now owned by the Government.

The second question imposes no limitation, and calls upon the Board to suggest "any other method" (apart from a Government foundry, pure and simple) by which the purposes of the act of Congress can be achieved. The Board is evidently called upon to consider the subject of joint action between the Government and private parties for the accomplishment of a national purpose.

The Board decided that there were three points of view from which this subject should be considered, viz.:

1st. That the Government should supplement the plants of some of the steel workers of the country with such additional tools and implements as would enable them to turn out finished steel cannon.

2d. That the Government should give contracts of sufficient magnitude to enable the steel workers of the country to supply the finished guns without its direct aid.

3d. That the Government should establish on its own territory a plant for the fabrication of cannon, and should contract with private parties to such amount as would enable them to supply from the private industries of the country the forged and tempered material.

The course of the investigation being thus indicated, letters were addressed to the Secretaries of War and the Navy, requesting any information in their possession relating to

I. Description, capacity, and cost of equipment of the European arsenals and foundries, capable of casting and manufacturing the largest guns.

II. Plans of the navy yards and arsenals, covering the following requisites:

Defensibility.

Possibility of expansion.

Convenience of proving and testing.

Proximity of iron, coal, and water communication.

Character of foundation.

Salubrity of climate.

There were no reports on file in the departments that could give any satisfactory information on I.; but, plans of the navy yards and

arsenals (II.) were furnished, accompanied by detailed descriptions.

The Secretaries were further requested to direct the Chiefs of Ordnance to communicate to the Board the views and plans best calculated to assist the object: the following replies were received:

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, May 8, 1883.

COMMODORE E. SIMPSON,
President of Board on Foundry, etc.

SIR: Your letter to the Honorable Secretary of War of the 1st inst., requesting "that the Chief of Ordnance may be directed to communicate to the Board such views and plans as may seem to him best calculated to assist the object in view," that is, the establishment of a national foundry at a navy yard or arsenal, or any other method, whereby heavy ordnance adapted to modern warfare can be manufactured, has been referred to my action.

1st. As to the *Navy Yards.*—The location of our navy yards, in close proximity to the entrance of our principal harbors, is a bar to their selection. The only exception is the Washington Navy Yard, and the objections to it are its distance from supplies of coal and metals, and from centers of skilled labor and manufacturing facilities.

2d. As to the *Arsenals.*—The principal eastern arsenals are the Watertown, Mass.; Watervliet, N. Y.; Allegheny, Pa., and Frankford, Pa. My preference is for the Frankford Arsenal, located near the great iron and coal center of the country, with rail and water communication, and yet at a safe distance from the sea-coast. It has all the advantages of a location in a large manufacturing city, with every facility for procuring skilled labor and machinery. My second choice is Pittsburgh.

3d. As to any *other method.* . . . The only other method is to assist and encourage some private foundry in establishing the plant necessary for such costly operations as the manufacture of heavy ordnance.

4th. I take it that whatever plan may be adopted, the final object to be obtained is the production of 100-ton guns. With this in view, the establishment of a national foundry will in the end cost many millions of money. A private foundry may be willing to co-operate with the Government, if the latter will provide some of the more costly plant, such as new furnaces, steam-hammers, large lathes, cranes, etc., the foundry to reimburse the Government by paying a certain percentage on all work performed with said plant until the whole cost is repaid. In the course of time—the length depending on the quantity of work annually ordered by the United States—the United States would be entirely reimbursed for the original expenditure, and the foundry become self-sustaining. It is believed that Congress would be more likely to approve of the smaller expenditure; and the foundry could supplement Government work by outside orders. Such a plan would combine in a marked degree and to the advantage of all concerned, private enterprise and activity with the so-called Governmental conservatism. If some practical scheme of

this sort can be decided upon, I believe it will prove the best for the early production of heavy ordnance. Provision of course should be made for the United States taking possession of the foundry at any time by paying the appraised value.

5th. In determining this question, the cost "of all buildings, tools, and implements necessary to be used in the manufacture thereof, including the cost of steam-hammer, etc.," comes in as a most important factor. The success of such an undertaking will depend on the money expended upon it, and Congress will be largely influenced by the financial aspect of the case. The dollars and cents to be appropriated must be determined and reported on to a nicety. How is this to be done? Such information can only be had at the foundries where such large plant has been erected and where such monster cannon have been manufactured. There is no such foundry in this country, and a safe and thorough solution can only be reached by personal inspection and study of foundries doing such work when in actual operation. I am satisfied that the Board should be ordered to visit the principal works and shops in England, France, and Germany. If it is in contemplation to produce the steel at the national or private foundry, then the question comes up, shall the steel made be by forging under heavy hammers, or by compression after the manner of Whitworth. And in this connection I desire to express my opinion of the great importance of a thorough study of the Whitworth plant; the uniform success which has obtained in the use of this steel in heavy ordnance, places it without a superior in all the qualities of steel for gun construction.

Respectfully, your obedient servant,

S. V. BENÉT,
Brig. General, Chief of Ordnance.

BUREAU OF ORDNANCE, NAVY DEPARTMENT,
Washington, May 11, 1883.

COMMODORE EDWARD SIMPSON, U. S. N.,
President of Foundry Board, Navy Yard, League Island, Pa.

SIR: Your letter of the 1st inst., requesting the Navy Department to direct the chief of this Bureau to communicate to the board his views with regard to a Government establishment (or other means) for the manufacture of modern cannon, is received.

The present views of the Bureau are much the same as those lately communicated to the Department, and which were referred to the Senate Committee on Appropriations,* under date of February 5, 1883. . . . .

If wire-winding attains a practical development, it will probably tend to lessen the amount of heavy-cutting machine work upon cannon.

It also appears quite possible that the tube may come to be the only large forging required in a gun; and the thickness of that even may, in the end, be considerably reduced.

These points are not, however, at all practically settled as yet, and we must still consider that the jacket (the most difficult forging to produce) is an essential feature of the construction of cannon, requiring a powerful hammer

* See page 548.

or other means of forging the mass. The hammer is the most evident agent for accomplishing this, and the one with which we are best acquainted.

Fluid compression is thought to have merit, and is practically established in England, where it is used in conjunction with forging or squeezing by hydraulic pressure. The Bureau unfortunately has no exact information as to the detail of the hydraulic-squeezing process, and is therefore unable to give any decided opinion on its merits.

It must, however, be said that the published results of tests of Whitworth steel are very favorable to this method; and as several large forgings have lately been ordered by the Bureau, of Sir Joseph Whitworth & Co., it is probable that an opinion on the product can be formed after the test of the tubes, jackets, etc., thus ordered.

It is not thought that the production of steel-gun ingots will offer any insuperable difficulty to the steelmakers of this country; but they are totally deficient in proper forging facilities for such a piece, for instance, as the jacket of an 8-inch gun, and only one or two could hammer a tube for that caliber.

It would thus seem that the creation of a proper plant for forging or squeezing is the point to which attention should chiefly be turned, as stated in the printed slip enclosed.*

There are a number of machine-shops in the country which could do the machine work on hooped guns, under proper superintendence.

Wire-winding will require a special tension attachment to lathes, with reels, etc., but it is not thought that the manufacture of such tools offers any special difficulty, neither does that of the wire-drawing apparatus.

I am, Sir, your obedient servant,

MONTGOMERY SICARD,

Chief of Bureau.

The following were addressed to several of the steel manufacturers in the country, and to the two companies employed in the fabrication of cannon:

[Copy of circular letter to steel manufacturers.]

COMMANDANT'S OFFICE, NAVY YARD, LEAGUE ISLAND,

Philadelphia, *May* 1, 1883.

GENTLEMEN: I forward herewith a copy of a precept issued by the President of the United States, under the provisions of an act of Congress, appointing a Board charged with the duties mentioned in the order. Besides the consideration of the establishment of a Government foundry, pure and simple, and the determination of the suitability for this purpose of any site now the property of the Government, the Board desires to be informed as to the disposition of the steel manufacturers in the country to assist the object to be obtained, namely, to enable the Government to produce at home from its own material and manufacture the heaviest ordnance required for modern warfare.

The Board is informed of the propositions made to the steel manufacturers by the Chiefs of Ordnance under dates of February and April, 1883, in which

* See page 549.

certain requirements are presented, but in the calls thus made, the size of the castings does not exceed what would be suitable for the tubes of 8-inch guns.

In considering the subject as now presented by the Board, your attention is asked to the fact that its interrogatories are intended to include the manufacture of steel guns up to 100 tons weight. It is further desired that you will carefully consider the methods of manufacturing gun-steel now employed in England, France, Germany, and Russia, with a view to the selection of any of the methods for its manufacture.

The Board requests that you will consider the following problem, namely: Given your present plant, what aid would you require from the Government in order so to enlarge it as to be able to manufacture the heaviest ordnance, the work to include the entire process of manufacture from the casting of the ingots to the finishing of the gun. The Board would require an itemized statement of buildings, tools, hammers, or apparatus, with estimates of cost.

Whether you conclude to consider this proposition or not, the Board requests a reply to its communication, and will be glad to answer any questions you may be pleased to present. Respectfully,

E. SIMPSON,

Commodore United States Navy, President of the Board.

[Circular letter to South Boston Iron Company, and to Paulding, Kemble & Co.]

COMMANDANT'S OFFICE, NAVY YARD, LEAGUE ISLAND,
Philadelphia, May 1, 1883.

GENTLEMEN: Referring to your communications of December 15, 1882, and January, 1882, to the honorable the Secretary of the Navy, and the Chief of Ordnance, War Department, in relation to the establishment of a plant capable of manufacturing the heaviest ordnance required for modern warfare, the Board asks your attention to the inclosed copy of a precept issued by the President of the United States in accordance with an act of Congress.

Your consideration is also requested of the inclosed copy of a communication addressed by the Board, constituted by the above-mentioned act, to the steel manufacturers of the United States.

The act of Congress under which the present Board is organized is in the direction pointed out by your communications above referred to, and the Board will be glad if you will revise your proposition and so modify it as to reply to the interrogatory submitted as a problem in the inclosed letter to the steel manufacturers, as follows: Given your present plant, what aid would you require from the Government in order so to enlarge it as to be able to manufacture the heaviest ordnance, the work to include the entire process of manufacture from the casting of the ingots to the finishing of the gun?

Respectfully,

E. SIMPSON,

Commodore United States Navy, President of the Board.

As above referred to, fourteen of our steel manufacturers were called upon to provide steel of open-hearth production, made from

the best raw material; the ingots, within finished dimensions, to be perfectly sound, free from all cracks, blowholes, and other serious imperfections; all parts to be thoroughly forged down as near as possible to the required limits; to be annealed, rough-bored, and turned, and to meet the tests laid down by the Bureaus. Attention was urged to very long sinking-heads and to the necessity of cutting the ingot from the bottom end of the casting in order to insure soundness and a uniform quality throughout.

In reply to a communication from the War Department, the Navy Chief of Ordnance submitted the following:

BUREAU OF ORDNANCE, NAVY DEPARTMENT,
Washington, March 20, 1883.

CHIEF OF ORDNANCE, *U. S. Army*,
Washington, D. C.

SIR: I have the honor to state in answer to your letter of the 14th instant, that the Bureau is at present unable to inform you which of our manufacturers possess the best facilities and experience for furnishing tubes, jackets, and rings for a steel gun of 8-inch caliber. No firm has yet been successful in producing 8-in. forgings of suitable quality for the guns the Bureau has in view.

At various times invitations to bid on 8-inch tubes and jackets have been issued to a number of the principal steel makers of the country, and replies favorable to undertaking such work have been received from the following firms:

Otis Iron and Steel Company, Cleveland, Ohio; Cambria Iron Company, Johnstown, Pa.; Park, Brother and Company (Black Diamond Steel Company), Pittsburgh, Pa.; Midvale Steel Company, Nicetown, Philadelphia, Pa.; Naylor and Company (Norway Iron and Steel Works), Boston, Mass.

Whether the firms referred to can really do the work is not known.

I am, Sir, your obedient servant,

MONTGOMERY SICARD,
Chief of Bureau.

The Chief of Army Ordnance addressed the following to thirteen of the leading steel manufacturers:

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, April 3, 1883.

GENTLEMEN: I enclose herewith drawings, giving the dimensions and weights for certain steel forgings, to wit: the tube, jacket, and trunnion-hoop for an 8″ breech-loading rifle, and the trunnion-hoop for a 12″ muzzle-loading rifled mortar, the construction of which is provided for by the Act of 1883 for the armament of fortifications, and request that you will inform this office whether you possess the facilities for manufacturing the same, of the qualities specified below.

Open hearth or Siemens-Martin steel is required. The ingots for the tube and jacket should weigh two and one-half times as much as the solid forgings, that the lower and sounder part only of the ingots may be used; and further, the diameter for the tube should be twice, and for the jacket as nearly twice as possible, the diameter of the finished forging, in order that the part of the ingots used may be drawn out under the hammer—that for the tube to four times its primitive length, and that for the jacket to not less than two and one-half times its primitive length—more is desirable. When turned to the diameters shown on the drawing, the forgings should be free from spots or soft places on the exterior.

The physical qualities of the forgings, ascertained from tests of rings cut from each end after treatment, should be as follows, viz.:

	Elastic Limit. *Tons.*	Resistance at Rupture. *Tons.*	Elongation at Rupture. *Per cent.*
Tube	18	38	18
Jacket	20	40	14
Trunnion-hoops	20	38	7

To obtain the above qualities, using a low steel, special treatment will be requisite, the precise steps of which, as well as the most suitable proportion of carbon, must be ascertained by experiment. The general mode of procedure would be thus: After forging, the tube is annealed, and specimens for test taken; if satisfactory, it is then rough-bored and turned, and tempered in oil that is kept cool by a current of water, the time of its immersion in the oil being brief; it is then a second time annealed.

The above is the method employed in France and Russia for the treatment of gun-steel, and differs, it is believed, from the process followed at the Royal Gun Factory and Sir William Armstrong's works in England, in annealing again after the oil tempering. Krupp dispenses with oil tempering altogether, claiming to attain equally good results by covering the ingots, when withdrawn from the mould, with hot ashes and keeping them so covered for months at a time, allowing the metal to cool very gradually. At the German works of Bochum also, and at Witten, gun steel is not oil tempered, as it is thought the process is attended with too much uncertainty. There, steel projectiles alone are tempered in oil. According to the Russian practice, it is stated, the tubes are allowed to remain in the oil tank only ten or fifteen minutes, and are then replaced in the heating furnace, from which the fire has in the meantime been withdrawn, and allowed to cool slowly.

The following tables, taken from French sources, give some data relative to the effect produced by this mode of treatment:

EFFECT OF TEMPERING AND ANNEALING ON CAST-STEEL FOR GUNS.

The following table shows the influence of hammering, tempering, and annealing at different temperatures on cast-steel run into ingots.

Treatment of the Bars.	Limit of Elasticity.	Ultimate Strength.	Elongation at Rupture.	Remarks.
	Tons.	*Tons.*	*Per cent.*	
Bars cut from the ingot in its natural state	15.7	28.7	6.0	
Bars cut from the ingot and then hammered	34.9	45.0	6.4	
Bars cut from the ingot and then hammered and tempered	27.3	52.5	10.3	Tempered in oil.
Bars cut from the ingot and then annealed at a yellow heat	20.6	35.5	11.9	
Bars annealed at a higher heat than the yellow	18.3	36.5	19.4	
Bars cut from the annealed ingot and afterwards tempered	24.7	48.0	7.4	Tempered in oil.
Bars cut from the annealed ingot and afterwards tempered and annealed	22.6	38.0	19.0	Tempered in oil.

The following results were obtained from several specimens of gun steel (Bessemer or Martin) forged and then tempered.

	Krupp Steel for Hoops.		Krupp Gun Steel.			Creusot Gun Steel.		
	Natural state.	Tempered in oil.	Natural state.	Tempered in water.	Tempered in oil.	Natural state.	Tempered in oil.	Annealed after tempering.
Elastic limit—tons per square inch	16.5	19.0	......	......	......	16.5	24.0	21.0
Elastic elongation—per cent	0.132	0.140						
Ultimate strength—tons per square inch	34.8	48.5	41.3	48.5	62.0	35.0	44.5	41.5
Elongation at rupture—per cent.	7.4	5.5	21.	4.5	1.0	18.7	13.0	16.5

This mode of treatment, by annealing after oil tempering, would seem to give a more suitable metal—one that combines a high elasticity with a considerable ductility—than any other mode of which this Department has information; and it is claimed that steel thus produced is rendered fairly homogeneous.

There will also be required for the two guns in question a number of steel hoops of the following dimensions, viz.:

Number of Hoops.	Outside Diameter, *Approximate.*	Inside Diameter, *Approximate.*	Width, *Approximate.*
	Inches.	*Inches.*	*Inches.*
For Gun. Total, 39. { 11	32.1	26.2	8.2
18	26.0	20.0	7.4
10	20.6	15.4	8.5
For mortar. Total, 14. { 6	41.6	35.8	9.0
8	37.0	29.0	11.0

The physical properties required for the hoops are as follows:

Elastic Limit........22 tons.
Resistance at Rupture........42 tons.
Elongation at Rupture........9 per cent.

The hoops would best be obtained by rolling, and the preference is given abroad to horizontal rolling mills.

In case you possess a tire-rolling mill, the alterations necessary to adapt it to the manufacture of gun-hoops should be determined with a view to rolling hoops of twelve inches width, if desired. A width of seven inches is the least that would be accepted, exclusive of the margin of one and one-fourth inches from which specimens for test are taken.

The hoops also, should the tests made for that purpose prove satisfactory and the operation be attended with certainty, would be oil tempered. This seems to be the practice at present in Europe, outside of Germany.

The data given below show the excellent physical properties of the oil-tempered hoops manufactured at the Creusot works in France, and Sir Joseph Whitworth's works in Manchester, England; the figures were furnished this office directly from those works.

Physical qualities of very large hoops furnished by foreign manufacturers for guns.

Manufacturer.	Elastic Limit.	Resistance at Rupture.	Elongation at Rupture.
	Tons.	*Tons.*	*Per cent.*
Creusot works. Cast-steel, tempered in oil	20.	39.	14.0
Whitworth & Co. Soft state	19 to 23	32 to 36	24 to 28
Whitworth & Co. Tempered in oil	25 to 30	40 to 50	15 to 20
Russian Government works. Tempered in oil	23.	37.	8.0

Sir Joseph expresses his ability to furnish a stronger metal than the above and still retain ample elongation for gun material. Of the admirable quality of his steel there is no question, and his method of compressing the metal in the fluid state, and afterwards of subjecting it again to pressure instead of hammering, would seem to be the very best treatment for securing a sound and homogeneous product. It is stated, but with what authority is not known, that when Whitworth tempers his steel in oil he afterwards anneals it. The tube

(oil-tempered) of the 12-inch Whitworth rifle tested at Gâvre gave a strength of 47.6 tons per square inch, with an elongation of twenty per cent.

The following table shows the influence of tempering on steel bars with different proportions of carbon :

Influence of Carbon.

The results of some experiments made at Terre-Noire, on steel bars 0''.8 in diameter and 7''.9 long, are here given.

Amount of Carbon.	Condition of the Bars.	Elastic Limit.	Resistance at Rupture.	Elongation.
		Tons.	*Tons.*	*Per cent.*
0.150	Raw state	11.0	23.0	32.5
	Tempered in oil	20.0	29.0	28.0
	Tempered in water	18.0	28.0	19.0
0.490	Raw state	15.0	30.0	24.8
	Tempered in oil	27.0	48.0	12.0
	Tempered in water	30.0	52.0	2.5
0.709	Raw state	18.0	39.0	10.0
	Tempered in oil	47.0	69.0	4.0
	Tempered in water	Broke in	tempering.	
0.875	Raw state	20.0	49.0	8.4
	Tempered in oil	58.0	68.0	1.0
	Tempered in water	Broke in	tempering.	
1.050	Raw state	25.0	56.0	5.2
	Tempered in oil / in water	Broke in	tempering.	
Sir Wm. Armstrong's experiments on a steel casting for a trunnion-hoop (unhammered).				
0.36	Before tempering in oil	16	27.8	7.5
	After tempering in oil	25	37.7	12.5

The Department will also require a steel tube for a 10'' rifle wound with wire. The diameter of the forged tube will be about seventeen inches and the length twenty-six and one-half feet.

It is to be hoped that all the steel for the experimental guns, to be manufactured this summer, can be procured from home manufacturers, so that the Department may be able to furnish the next Congress with such information, as to the ability of our steelmakers to produce suitable gun forgings, as will warrant the request for a liberal appropriation for the production of steel guns; thus, we may hope to develop gradually our home facilities until we are in a condition to manufacture steel guns of the largest caliber. It is believed the steel can be furnished if, for the present, the steelmakers will co-operate with one another, the works possessing the best furnaces, for instance, casting the ingots, and then arranging with the works possessing the heaviest hammers to do the forging until their own facilities are sufficient for the purpose.

It is the desire of the Department and the intention of the law to depend on home products exclusively, if possible; but if the heavier forgings must now be procured abroad, the lighter ones may still be produced here. Rolled hoops, especially, should be manufactured here with comparatively little delay or trouble.

Should the proposed 12″ experimental mortar, cast-iron, hooped with steel, prove successful (as there is every reason to believe it will, from the good results obtained with like constructions abroad), it is the intention of the Department to make application to Congress for sufficient appropriations to fabricate a considerable number of such pieces. The manufacture of steel hoops is one of the first and simplest steps in the production of gun steel, and has been in successful operation abroad even where the industries were unable to produce the larger and more difficult forgings required for gun tubes.

It is urged upon our steelmakers to give this subject their serious consideration. The Department desires to give all possible assistance and encouragement in this matter.

With your reply I should be pleased to have an expression of your views generally upon the subject matter of this letter.

Very respectfully, your obedient servant,

S. V. BENÉT,

Brig. Gen., Chief of Ordnance.

The following replies to the circular letter of the Gun Foundry Board were received:

6 Oliver Street,

Boston, May 8, 1883.

Sir: We have the honor to acknowledge the receipt of your circular letter dated the 1st instant, addressed to us, and also one of similar tenor addressed to the Norway Iron Works.

In reply to the same we regret to be obliged to say that, owing to contemplated changes at our works, we cannot at present hold out any prospect of being able to furnish the Government with steel guns such as are mentioned in your letter. Should we, at a later date, be in a position to supply them, we shall then be happy to take up the matter and furnish the Board with estimates.

We are, Sir, very respectfully, yours,

NAYLOR & CO.

Commodore E. Simpson, U. S. N.,

President of the Foundry Board, Navy Yard, League Island, Philadelphia, Pa.

West Point Foundry,

Cold Spring, May 10, 1883.

Sir: We beg leave to acknowledge the receipt of your communication of May 1. The problem proposed to us is a difficult one, and we would inquire how much time you can allow us to look into the matter.

We would also ask you if you are correct in assuming that guns will be required from 6-inch to about 16-inch caliber, and if you can give some idea of the number of each kind which such an ordnance establishment should produce in the course of a year to meet the wants of the Government.

Very respectfully, your obedient servants,

PAULDING, KEMBLE & CO.

Commodore E. Simpson, U. S. N.,

President of Board, Navy Yard, League Island.

PARK, BROTHER & CO.,

Pittsburgh, Pa., May 10, 1883.

DEAR SIR: We are in receipt of your esteemed favor of 1st instant, and carefully note contents. We will take the matter into consideration, and write you further on the subject in a few days,

Yours truly,

PARK, BROTHER & CO.

E. SIMPSON, Esq.,

Commodore United States Navy, President Foundry Board, Washington, D. C.

OFFICE OF THE SOUTH BOSTON IRON WORKS,

70 *Water Street, Boston, May* 12, 1883.

SIR: I have the honor to acknowledge receipt of your communication of 1st instant with inclosures named. I have given much consideration to the subject concerning which you make inquiry, and realize its great importance. I propose to thoroughly study the question and obtain expert assistance in making such investigation, and in preparing such estimates and plans in detail as will enable me to present to your Board the design of a practicable plant for the manufacture of heavy ordnance adapted to modern warfare, including a steam-hammer or apparatus of sufficient size for the manufacture of the heaviest guns.

It will be three or four months before I shall have completed this work, as I contemplate a visit to the important establishments in Europe for consultation and observation.

Meanwhile, I remain very respectfully, your obedient servant,

WM. P. HUNT,

President South Boston Iron Works.

Commodore E. SIMPSON, U. S. N.,

President, &c., Commanding League Island Navy-Yard, Philadelphia.

PITTSBURGH, PA., *May* 22, 1883.

DEAR SIR: Your favor under date of May 1 is at hand. Replying thereto, we beg to say that we fear the expense of altering and adding large additional machinery to our present plant, which is new and improved, would be more than the Board would entertain. Our location in this market we claim is as good, if not better, than that of others for the shipping and hauling of heavy shapes, either by the Ohio river or by rail, and if the extra machinery was added to our plant, the ordnance required could be produced as cheaply and as effectively as at any other point in the country.

We would not entertain a proposition that would leave us high and dry when the present honorable commission retired, but must be guaranteed or subsidized for at least ten or fifteen years. This would insure safety to ourselves for changing or allowing to be changed, our present plant, which is already adapted to turning out in the neighborhood of 12,000 tons of steel per annum, and would, we feel, be more satisfactory to the Government.

If the honorable Board would outline for us the size of plant governed by the number of guns, tonnage, &c., required, and about the sum the Government

would limit itself to invest, we could more accurately inform ourselves what would be necessary.

We are, Sir, yours respectfully,

PITTSBURGH STEEL WORKS,
ANDERSON, DU PUY & CO.

Hon. E. SIMPSON, ESQ.,
Commodore United States Navy,
President Board of Ordnance, Philadelphia, Pa.

THE MIDVALE STEEL COMPANY,
Nicetown, Philadelphia, May 26, 1883.

DEAR SIR: Your circular letter of May 1, calling the attention of this company to the existence of the Board of which you are president, and to the object for which it has been created, came duly to hand and would have received a more prompt acknowledgment had we not been prevented from presenting the matter to the attention of our president, Mr. Wm. Sellers.

This company has given the subject of the manufacture of steel for ordnance considerable attention, and has had some success in the production of pieces of moderate size—such, for instance, as are required for 6-inch breech-loading guns.

Our capacities are at present very limited for this sort of work, heavier than the above mentioned; but, from our past experience, we feel confident that in case we could be insured a sufficient amount of work to make the undertaking remunerative, we could, with proper appliances, produce successfully large masses of steel for ordnance purposes.

In considering the matter with a view of answering the Board's inquiry as to what additions would have to be made to our present plant in order to enable us to produce the parts of a 100-ton steel gun, we would now ask the Board to kindly furnish to us the approximate dimensions of the largest masses of steel required in the construction of a gun of this weight. We could then consider, more intelligently, the problem in question.

Awaiting the Board's reply, we remain,

Yours respectfully,

R. W. DAVENPORT, *Superintendent.*

Commodore E. SIMPSON, U. S. N.,
President Foundry Board, Navy Yard, Philadelphia.

PITTSBURGH, PA., *May* 24, 1883.

DEAR SIR: Referring again to your esteemed favor of 1st instant, would say our Mr. William G. Park will probably be in Philadelphia within a week and will then see you and discuss the subject thoroughly.

Yours truly,

PARK, BROTHER & CO.

E. SIMPSON, Esq.,
Commodore United States Navy,
President of Foundry Board, League Island, Philadelphia, Pa.

SPRINGFIELD, ILL., *June* 2, 1883.

DEAR SIR: Your letter of May 1, in regard to the establishment of works for the manufacture of heavy steel guns, was duly received and has been considered. In reply, I have to say that this company has a plant consisting of three "Pernot" open-hearth steel furnaces, so arranged that we can readily cast ingots weighing say 40 gross tons. We could also easily arrange to increase the weight to 50 tons, and by the addition of one or two furnaces to 75, or even as high as 90 tons. I am not very familiar with the nature of the tools and other appliances which would be necessary to finish the different parts of the gun from the ingot; but suppose we have but little, if anything, in our plant that would apply. For this same reason I am not prepared to furnish an estimate of the amount of aid which we would require to enable us to prepare ourselves for the undertaking which you have in view. I can say, however, that we would be glad to co-operate with the Government in establishing a plant of the kind wanted, and that we would fit up our works with everything necessary upon being satisfied that it would receive a fairly remunerative business by so doing. Or we will, if it is preferred, and time can be given, procure estimates of the cost of whatever may be needed, and allow the Government to furnish the same on any fair understanding as to what compensation we shall receive for the use of what we now have. In this latter case, we would request that you furnish the specification for an outfit of such a kind as you think will be best adapted to the purpose in view.

We think that this place affords some advantages for the business in contemplation. It is far enough inland to be at all times safe from interference from a foreign foe. Our transportation facilities are ample. We have an abundance of exceedingly cheap fuel and easy access to the best raw materials to be had in Missouri or on Lake Superior.

This company has been operating an iron-rail mill and bar mill very successfully for about twelve years, and is just completing a large mill for rolling steel plates of any thickness, and up to 110 inches wide. It is expected that this mill will be fully equal to anything of the kind in the country. It is possible that it may be to the advantage of the Government to take some ship plates from this mill at some future time for use at some of the various navy yards or on the western interior waters. It is also possible that our bar mill may be of use in furnishing some of the lighter parts to be used in the manufacture of steel guns of moderate weight.

Asking the favor of a reply, I am yours respectfully,

C. RIDGELY,
President.

Commodore E. SIMPSON, U. S. N.,
President Foundry Board, League Island, Philadelphia.

"The replies were unsatisfactory, the subject being a new one to the parties addressed. The expense to be incurred could not be calculated upon any known basis, and the Board was unable to satisfy the calls made upon it for further information

as to the number of guns required or the probable extent and cost of a plant for the manufacture of such heavy guns as the act of Congress contemplated.

It was evident that none of the desired information could be obtained from our manufacturers, because of their lack of experience on this subject. It was known, too, that several of the European Governments had had more or less experience of joint action with private artillery establishments. The call by the act of Congress for "the cost of all buildings, tools, and implements for the manufacture of the heaviest guns" could be answered only by information and experience obtained from abroad, as no such tools or implements have been manufactured or are in use in the United States. The steam-hammer mentioned in the act was recognized as a subject requiring careful consideration. It is coupled with a qualification, "or apparatus of a sufficient size," which indicates that there existed a doubt as to the propriety of the use of a steam-hammer for forging if other "apparatus of sufficient size" could be made more efficient. The advances made of late years in the process of forging by compression made this a very important matter for consideration. This subject is necessarily connected with that of the manufacture of the metal to be forged, and involves a study of the recent developments in steel. The actual condition of the armaments abroad, so far as it illustrates the latest ideas, was felt by the Board to be an important part of the information on which it should report, as the character of the new constructions of cannon would necessarily control that of the tools to be recommended for use in their fabrication.

The foregoing reasons governed the Board in its decision to represent the necessity of seeking information abroad. Orders were issued and the Board proceeded to Europe. The first visit was made to England."*

* Gun Foundry Board Report.

II.

ENGLAND.

Sources of Supply and Condition of Artillery.

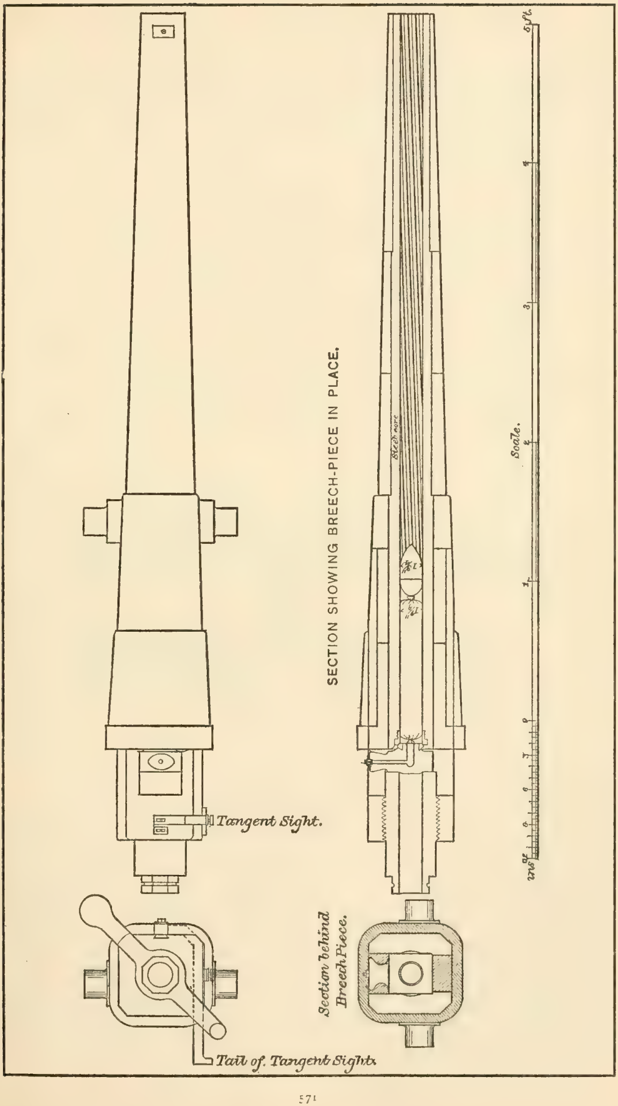
In reply to the requests of the Board, the most cordial responses were given by both government officials and private companies; and at all of the establishments visited, every opportunity was given for the investigation of their special productions, with one exception. Messrs. Vickers, Sons & Co., of Sheffield, decided, that in view of the severe competition of the time, they were not called upon to show their methods of producing steel.

> "Previous to the year 1859, the Royal Arsenal of Woolwich was the only source from which the armament of England was supplied. The arsenal was a purely governmental establishment, in which there were several departments. The department of the Royal Gun Factories was always under the command of an officer of the Royal Artillery; and here all cannon for the army and navy were fabricated.
>
> Since the year 1859, the Elswick Works, at Newcastle-on-Tyne, has been a source of supply on which the Government has drawn more or less for guns. The experience of the connection of the English Government with these private works bears directly upon the subject of joint action between a Government and a private firm.
>
> This connection dates from the time when attention was called to the improvements in rifled ordnance inaugurated by Mr. William G. Armstrong." *

The Armstrong gun was first brought to the notice of the Government in 1854, and Mr. Armstrong was authorized by the Duke of Newcastle to construct one or more guns on the plan suggested, and to make the necessary experiments at the government expense.

In July, 1855, a 3-pounder (Plate I.) was delivered, with a report of the experiments that had been made with it. In its production, Mr.

* Gun Foundry Board Report.

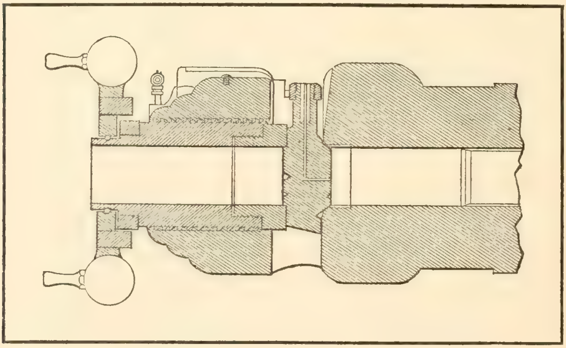


ORIGINAL ARMSTRONG GUN.

Armstrong not only presented it as a test of his system of gun-construction, but also gave attention to breech-loading, mechanical arrangements to counteract recoil, facility of laying and pointing, and the tensile strength of materials suitable for gun-construction. The following is a description:

A core, or internal lining for the gun, was formed of cast-steel, to which the requisite strength was given by encircling it with twisted cylinders of wrought-iron, made in a similar manner to gun-barrels, and tightly contracted upon the steel core by the usual process of cooling after previous expansion by heat; the parts are then in that state of initial tension which is necessary to bring their entire strength into operation. Considerable difficulties were encountered in carrying this plan into practice.

The arrangement for loading at the breech consists of a powerful screw having a hole through the centre in the prolonged line of the bore, through which hole the bullet and charge are delivered into the gun.



BREECH-MECHANISM---ARMSTRONG 110-POUNDER.

A breech-piece with a mitred face, fitting a similar face at the end of the bore, is dropped into the recess, and by the action of the screw pressed tightly into its seat, so as effectually to close the bore. The fitting services which close the bore were at first made of unhardened steel; this failed. Hardened steel was next used, but this yielded to the action of the powder more rapidly than before; copper was then tried and no further difficulty experienced. The breech-piece contains the vent.

The bore is 1¾ inches in diameter, and contains eight spiral grooves, having an inclination of one turn in twelve feet; these grooves terminate at a distance of fourteen inches from the breech, and the bore then gradually expands in a

length of three inches, from 1¾ inches to 1⅞ inches in diameter. The bullet, in the process of loading, passes freely through the widened space; but, its diameter being a little in excess of that of the bore, it lodges in the tapered contraction of the commencement of the grooves. The weight of the gun by itself is about 5 cwt. Including the carriage, the weight is about 15 cwt., which is nearly identical with that of the light 6-pounder brass gun and carriage of the service. The weight of the projectile (composed of lead, hardened with antimony and tin) is three pounds. A long course of experiments was made to determine the best form; numerous forms were tried, and Mr. Armstrong was of opinion that experiments should be continued in order to arrive at perfection. The form last used was a cylinder, pointed in front, with a conical end behind. The charge was fourteen ounces of fine blasting powder. There is an ingenious arrangement for absorbing the recoil, and another by which the pointing and elevating are expeditiously and correctly performed. The gun was brought to Woolwich for inspection, and was then sent to Shoeburyness for experiment. Mr. Armstrong stated that 800 rounds had already been fired from it. At Shoeburyness, 100 rounds were fired at elevations varying from ¼° to 7°. A very long range was obtained; though it was not always uniform, the direction was extremely accurate. The shot did not proceed point foremost after the first graze. All the shots that were recovered showed marks of their having completely taken the rifle-grooves. A considerable escape of gas took place at the breech; the gun was loaded with great facility, and pointed quickly and accurately; the recoil was checked, but not entirely absorbed by the action of the slide on which the gun is mounted. After the completion of these experiments, Mr. Armstrong, believing the gun was stronger than necessary, sent the gun back to Newcastle, to be re-bored up to a 5-pounder, and to make some alteration in the rifling by which he expected to obtain increased accuracy.

"In December, 1856, it was tried; the report stated that good practice was obtained at 1500 and 2000 yards. In January, 1857, a second gun was ordered. It was an 18-pounder, and was tried in January, 1858. The report was favorable, and the gun was so far approved as to cause the recommendation that two should be issued to the artillery to 'knock about, and be reported on as to their endurance of work in comparison with the service guns.'

In 1858 there arose a pressure for a supply of rifled field-guns for the army, and a committee, after investigation, reported that it was expedient to experiment only with the Armstrong and Whitworth guns.

There has always been a controversy as to the manner in which the comparison between these two guns was made; but the result of the trial was the adoption of the Armstrong system for field service, which at this time involved the follow-

ing combination of construction, viz.: breech-loading, rifling, and coating the projectile with soft metal." *

Mr. Armstrong considered that rifled guns of this construction would be especially valuable where long range was required. He believed that he attained strength, durability, range, and accuracy by the system he had advanced. He described this method as the *coil system*, and gave the following definition:

The construction of the gun is by a system of coiled tubes. I most approve of steel for the barrel when I can get the proper material; but if not, then the alternative is to use coils for the barrel as well as for the external parts. The most prominent feature is the construction; rifling is subordinate; the relative merits of the breech-loader and the muzzle-loader is a very difficult question, and neither mode is peculiar to my system. The use of soft material for giving rotation, either in the form of a continuous coating, or in the form of studs, is an essential point. Respecting the construction of heavy ordnance by the process of twisting wrought-iron bars into cylinders, and combining them in the manner described, I believe no difficulty will be experienced if proper apparatus be provided. I do not recommend the breech-loading principle to be applied in such cases because the movable parts will be too cumbrous to be conveniently handled.

Though the Armstrong *coil system* was adopted, the controversy continued, and in 1863 great prominence was given to the opinions of the principal exponents of the *built-up* and *coil* systems. Neither advocated the general application of breech-loading, but each advocated a special rifling. Joseph Whitworth, Esq., said:

I believe wrought-iron, that is to say, welded, metal is the very worst material you can use for a gun. With regard to the welding of the coil, supposing the metal to have a strength of 20 to 22 tons, the weld is found to have a strength of not more than 14 or 15 tons; the strength of the homogeneous metal I recommend is about 40 tons and has no welds; hence the tube must be infinitely better if made of homogeneous metal. It is highly desirable that it should be of right temper and properly manipulated. I am convinced that no large gun of welded iron will stand. I utterly condemn welded iron in a gun at all, either for the inner tube or for the coil. I go with Krupp, of Essen, the manufacturer of homogeneous metal. He is so satisfied with his material that he goes to a large size; though his metal is good, I think he has not always sufficiently annealed it. In my system of manufacture, the tube of the gun is made taper, being in the 5½-inch gun one inch larger in diameter at the breech than at the muzzle; then a series of hoops are made, which are screwed together so as to form another tube; that is put on by hydraulic pressure; then the requisite tubes follow in the next series in the same way, being turned

* Gun Foundry Board Report.

taper and pressed on. We do not anneal the hoops; we keep them harder for strength, so that in the case of homogeneous metal for hoops we have a stronger metal surrounding the tube, which will produce guns of great endurance. The system of rifling that suggested itself to me, as best adapted to this construction of guns, was the polygonal, as it afforded mechanical facilities for its employment. I adopted it; and the more experience I had of its use, the more its advantages developed themselves, both with regard to guns and projectiles; and I now feel quite sure that it is the best system that can be employed. It enables projectiles of the simplest character to be used; they are the cheapest that can be made, as they are easily produced by self-acting machinery. They cause very little wear from friction, as they have great extent of rifling surface. It is little liable to injury and affords great facility for loading easily. Though the system of rifling adopted by me is termed the hexagonal system, the section is not a real hexagon. Windage is provided for by easing off the half of each side; also, in making the flat sides of the hexagon, part of the original bore is left in. These modifications are most important. The projectile has six flat sides and six rounded surfaces, making twelve.

The peculiar features of my system of rifling are: the polygonal form of bore; a rapid rifling turn, giving much quicker rotations and greater length of projectile; and reduced diameter of bore, by which I have less resistance of air. Above all, I consider simplicity, durability, and economy.

Sir Wm. Armstrong was equally positive in the expression of his opinion:

The safety of my principle I consider has been established by the fact that out of nearly 3000 guns, not one has burst explosively, and no gun has failed under the most trying tests, excepting by a gradual process which has given timely notice of the approaching destruction, and has prevented any possibility of a dangerous accident.

To make large guns on the principle of solid forged tubes, either of steel or iron, I consider entirely out of the question, because we can never penetrate the interior of the mass so as to discover the existence of flaws.

In the case of wrought-iron it is difficult, even with a block large enough to make the internal barrel, to avoid flaws and soft places; and that difficulty would be very much increased if the entire gun was made up of such a mass. In short, I feel perfectly satisfied that the principle of construction which is exemplified in my original gun is the best that has yet been brought forward, and I see very little prospect of its being superseded. The only question is whether we can obtain the proper material for a steel barrel with uniformity of quality. Mr. Whitworth, who is my chief opponent in this matter, admits the propriety of the built-up system as applied to large guns. We are both agreed with respect to the expediency of using the steel tube; but he contends that the external parts of the guns, as well as the internal, should also be constructed of steel. Upon this point I entirely differ from him. I consider, that although steel is, as he states, very much stronger in a tensile point of view, yet that it is not so strong as wrought-iron as regards concussive strains. There is no diffi-

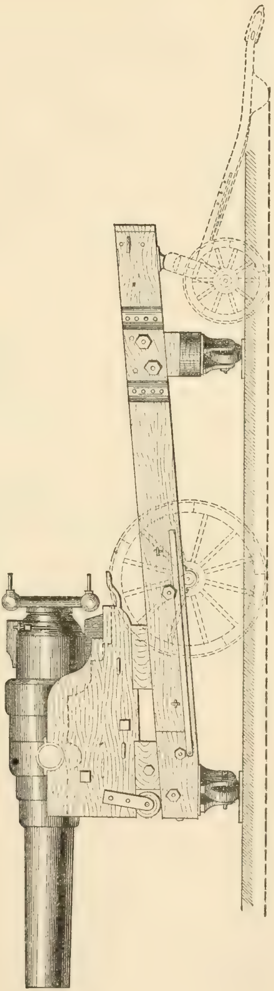
culty in making wrought-iron coils, so as to give requisite strength; and as they are cheaper, you can have no inducement to substitute steel cylinders foi the coiled hoops which I have hitherto adopted. From the very first I did not pledge myself exclusively to breech-loading; though it has great advantages, breech-loading guns would be heavier than muzzle-loaders, and this increase of weight becomes a formidable objection.

To-day all authorities concur that steel, *homogeneous metal*, is the best material for ordnance; breech-loading is universally accepted, and Sir Joseph Whitworth may yet live to see the polygonal system of rifling adopted as the most economical, durable, simple, and effective.

> "In order to obtain as soon as possible a supply of these guns, it was decided to supplement the resources of Woolwich by entering into arrangements with a company set up at Elswick for the manufacture of the guns and projectiles. A guarantee was given to this company on the 16th of January, 1859, to secure them against loss by the erection of buildings and machinery. The Government undertook to keep them in full work, but reserved the right to terminate the engagement on the payment of compensation. The necessities of the service requiring a larger number of these guns to be provided than was at first anticipated, the original guarantee was increased, first to £50,000, and then to £60,000. In October, 1859, owing to increased pressure for guns, the guarantee was raised to its final amount of £85,000.
>
> Sir William Armstrong was, on the 22d of February, 1859, appointed engineer of rifled ordnance, and on the 4th of November, 1859, he became also the superintendent of the Royal Gun Factories, which office he held until February, 1862. This was the first time that office had been filled by a civilian.
>
> In September, 1859, the 40-pounder Armstrong gun was approved for the navy. Proposals were also approved for the construction of a 110-pounder gun (Plate II.), and one hundred of these guns were constructed before any experiments with them had been concluded."*

They were adopted because of the confidence in the Armstrong system, and the extensive pressure for rifled guns. There was no time for experiments. They were made under the authority of the Government to construct as powerful a gun as possible within the

* Gun Foundry Board Report.



ARMSTRONG 110-POUNDER.

limits of weight and length. They were built on the principle of the original gun, and although Sir William was satisfied with every part except the vent-piece, the reports of inspection and proof indicated the marked, though not dangerous, weakness of construction and strengthening material. The guns were tested with charges of from 25 to 27½ pounds of powder, the service charge being from 11 to 14 pounds. Of four guns under trial, "three showed a separation on the outside between the trunnion-ring and the coil behind it; this separation is at the top of the gun, not at the bottom, and the guns were bent. The fourth showed the separation all around, but to less extent. All the guns expanded in the shot chamber and part of the powder chamber, and the bores were elongated. The appearance of the guns indicated a pressure at the seat of, and behind, the shot greater than the strength of the material used could resist."

> "The Government was thoroughly committed to the Armstrong system, and the manufacture was carried out at Woolwich by the Government, and at Elswick by a private company.
>
> The large expenditures having attracted attention, a committee was appointed in 1862 to inquire into them, and in April, 1863, the agreement with the Elswick Company was terminated by the Government, which discontinued all orders to it and concentrated its work at Woolwich. The guarantee of £85,000 was paid, the Government, however, being credited with the value of plant and stores, estimated at £19,000, making the amount in money paid £65,534 4s.
>
> The committee reported that during the continuance of the agreement with the Elswick Company the following sums had been paid:
>
> (1) The sum of £965,117 9s. 7d. for articles supplied.
>
> (2) After giving credit for the value of plant and stores received from the company, a sum of £65,534 4s., as compensation for terminating the contract.
>
> (3) The outstanding liabilities of the War Office to the Elswick Ordnance Company, for articles ordered, amounted on the 7th of May, 1862, to the sum of £37,143 2s. 10d.
>
> The whole of these payments and liabilities amounts to the sum of £1,067,794 16s. 5d.
>
> During the same period there had been expended in the three manufacturing departments at Woolwich on the Arm-

strong guns, ammunition and carriages, the sum of £1,471,753 1s. 3d., making altogether a grand total of £2,539,547 17s. 8d.

A statement prepared by one of the assistant accountants-general of the War Office shows the cost of certain guns and projectiles obtained from the Elswick Ordnance Company compared with the rates of those produced at the Royal Arsenal at Woolwich. According to this statement, taking the class of stores which have been supplied from Elswick and from Woolwich and which therefore admit of a direct comparison, the sum of £242,173 10s. 6d., on an expenditure of £593,275 10s. 11d., would have been saved to the public had these guns, projectiles, and fuzes, supplied by the Elswick Ordnance Company, been manufactured in the Royal Arsenal.

The evidence on this subject is acknowledged to be somewhat conflicting. Col. Boxer, who was the superintendent of the Royal Laboratory at Woolwich, and the accountant-general of the War Office state their belief that the statement is substantially correct, while Mr. Rendel and Captain Noble, R. A., partners in the Elswick Company, object to the basis on which the prices at the Royal Arsenal were ascertained; but there seems no doubt a saving would have been effected if all the articles had been manufactured at the Royal Arsenal.

The above is a statement of facts which exhibits the experience of the English Government in its experiment of joint action with a private company. The plant put up by the Government became the property of the private company at a nominal valuation, and the Government paid about £65,000 to break the agreement, besides paying an increased price on articles manufactured for it.

Elswick.—The subsequent history of the Elswick Ordnance Company under the control of Sir William Armstrong is well known. The plant for the manufacture of cannon has been kept employed by orders from foreign governments, and during late years much work has been done for the English Government. The enterprise and ability in its management has been of great assistance to the country, and at the recent re-adoption of the breech-loading system, the Government found Elswick prepared to assist in advancing the manufacture.

Thus, though there seems to have been no profit to the Government in working jointly with the Elswick Company,

much aid has been derived from it as an independent assistant, and it may be said that it is the only one which supplements the royal factories in finishing guns."*

The works now known as those of "Sir William G. Armstrong, Mitchell & Co. (Limited), Elswick, Newcastle-on-Tyne," were first started as a small engineering establishment by Messrs. Donkin, Crudas, Potter & Lambert. They were joined in 1847 by Mr. Armstrong, who for eleven years had been applying himself to the study of hydraulic machinery. He designed a machine combining the use of pistons with the continuous rotation of a water-wheel, which was described in the *Mechanic's Magazine* in 1838. It remained unnoticed; and though he continued the development, no progress was made towards a practical application, until 1846, when a crane of 5 tons was completed and erected for use upon the Newcastle quay. Its success was complete.

The development of hydraulic machinery has been very rapid, and to-day Sir William Armstrong's name is connected with every kind of water-pressure machinery, from an hydraulic riveter to the Spezia 160-ton crane. The hydraulic machinery manufactured at Elswick includes cranes, hoists, capstans, rotary and pumping engines; swinging, draw and lift bridges; machinery for opening and closing dock-gates and sluices; bands and elevators for discharging and storing grain; hydraulic pumps and winding engines for mines; also the boilers and steam pumping engines and accumulators for supplying the water under pressure.

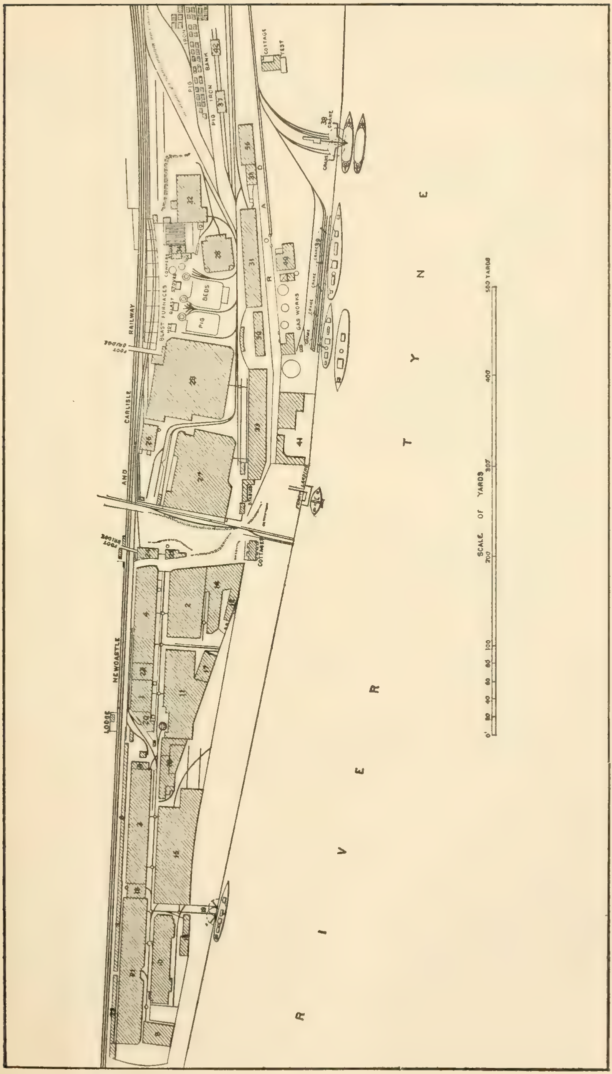
A few years after his establishment there, Sir William devoted his attention to the improvement of field artillery, and in 1858 an ordnance department was added to the Elswick Works.

These works are situated on the banks of the Tyne just outside of Newcastle, and have a river frontage of nearly a mile, but an average width of only 150 yards. They cover an area of 40 acres, and are bounded on the land side by the Newcastle and Carlisle Railway, alongside of which and parallel run the highroad and tramway from Newcastle to Scotswood.

LEGEND. (Plate III.)

	Ft.		Ft.
1. Gun Boring and Turning Shop	90	×	80
2. Gun Boring and Turning Shop	220	×	110
3. Smiths' and Boilerwork	360	×	70
4. Forge and Steam Hammers	320	×	80

* Gun Foundry Board Report.



PLAN OF ELSWICK ORDNANCE WORKS.

5. Pattern Shops	310 × 20
6. Chainmakers' Shop	390 × 20
7. Painters' Shop	40 × 20
8. Stables	60 × 20
9. Pattern Shop	100 × 70
10. Erecting Shop	390 × 65
11. Gun Boring and Turning Shop	307 × 140
12. Fuze Factory	110 × 45
13. Joiners' Shop	120 × 40
14. Gun Finishing Shop	145 × 55
15. Bridge and Girder Yard	405 × 120
16. Engine and Boilers	70 × 60
17. Gas Producers	80 × 40
18. Offices	....
19. Jetty, with two Hydraulic Cranes	....
20. Engine and Boilers	60 × 60
21. Fitting and Turning Shop	480 × 80
22. Boilers	....
23. Brass Foundry	380 × 25
24. Boilers	80 × 40
25. Engines	....
26. Boilers	75 × 35
27. Foundry	260 × 200
28. 35-Ton Steam Hammer	125 × 110
29. Gun-Carriage Shop	206 × 200
30. Joiners' Shop	140 × 38
31. Smiths' Shop	330 × 60
32. Coiling Shop	50 × 70
33. Projectile Shop and Stores	355 × 70
34. Blowing and Hydraulic Pumping Engines	....
35. Locomotive Shed	....
36. Gas Producers	125 × 45
37. Pit for Building up Heavy Guns (Shrinkage Pit)	....
38. Jetty for 120-ton Shears and Two Hydraulic Cranes	....
39. Jetty, with Five Movable Hydraulic Cranes	....
40. Hydraulic Pumping Engines	....
41. Pattern Stores	....
42. Special Rifling and Boring Shop	50 × 20

The shops, which have been erected as needed, are very much crowded and badly placed, owing to their situation on a narrow side hill. The rail and water facilities for transportation to and from the works are good. Six locomotives find employment within the works.

> "The establishment at Elswick is thoroughly equipped for heavy work and has produced the largest guns in the world."*

* Gun Foundry Board Report.

The foundry contains ten cupola furnaces, four of which are usually at work. The maximum castings usually made are about 40 tons, but much larger ones—notably that of 137 tons for the bed of the steam-hammer—have been cast here.

The coiling-machine differs from that at Woolwich, in that the mandrel with its turning gear is arranged to traverse laterally in front of the furnace, in order to avoid dragging the bar sideways over the furnace floor at the point of exit. The length of the furnace is 180 feet. The shops are all well provided with hydraulic cranes and rope-driven travelers. In the boiler shop, Tweddel's portable hydraulic riveter is in use.

"The shops are supplied with an abundance of fine tools,"* placed both across and lengthwise. One of the finest is a lathe of Whitworth's for turning, boring, screw-cutting, and rifling, with a capacity of 44 feet length and 36-inch centres. Another very important tool is one made by Fairbairn, Kennedy and Naylor, but modified at Elswick, which takes a chuck job 20 feet in diameter and 4½ feet long, or a job 34 feet long and 8 feet in diameter; it has slide-rests on independent beds.

> "The forge arrangements have been, up to the present time, all that was required for the manufacture of the guns heretofore turned out. But a change is being made in some of the details to better accord with the demand for steel cannon, and steel works are being erected capable of casting 100-ton ingots. Blast furnaces are also in operation."*

The pig products of these smelting furnaces, averaging 1000 tons per week, are made from Spanish and Elba ores, and are sold almost exclusively for steel-making.

> "The fact that the Government has abandoned the wrought-iron gun impairs the usefulness of the broad tup-hammer with which the wrought-iron coils were welded, and this is being modified to be more effective for forging steel ingots and hoops."*

It was constructed by Messrs. Thwaites and Carbutt, of Bradford, and had a 30-ton tup with 12-feet stroke, and a steam cylinder 48 inches in diameter. The frame was simple and massive, and was composed of two standards of circular section tapering in diameter and inclined towards the top. These standards, each made in two sections, were 25 feet high, and the total height of the hammer from

* Gun Foundry Board Report.

floor-line to top of cylinder-cover was about 43 feet. The clearance between standards at floor-line was 19 feet, 10 inches.

The modified hammer has a tup of 35 tons with a 15-feet stroke. It has steam above as well as below, but has never been used, as it was not necessary in forging iron; steam pressure, 50 lbs. No experiments have yet been made with it in forging large masses of steel. The foundation rests upon bed-rock; the anvil-block weighs 300 tons, and the anvil, 120 tons. Besides the large hammer, there are several smaller ones, and a number of re-heating-furnaces all constructed on the Siemens regenerative principle.

> "The advantages of the Whitworth manufacture are also recognized and a forging press is being introduced."*

The shrinkage and tempering pits are alongside of each other, that a single crane may be economically employed. The oil well is 50 feet deep. The gun-tubes, jackets, and hoops are received from the steel manufacturers rough-bored and rough-turned; some tempered ones are also received. They are then tested in the same way as at Woolwich, with the exception of the shock test, which is omitted. The machine employed is hydraulic and was manufactured here.

In the fabrication of guns, the tube is turned to nearly the size required for the reception of the jacket and hoops. It is then tempered in oil and finish-turned to receive the strengthening parts. In tempering, the tube is sometimes bent and there is a slight change in the diameter of the bore. Finish-boring and grinding are, therefore, usually done after tempering.

To assemble the parts, the tube is placed vertically in a pit, muzzle down, and plugged to prevent the escape of the water pumped into the breech end to keep the tube cool. The jacket is raised to the required *red* heat, and by the hydraulic crane taken from the furnace and lowered into its place around the tube. Gas and water jets are employed to heat and cool any portions that require it. A varying contraction of the tube takes place, sometimes amounting to .07 of an inch.

When cool, the gun is put into a lathe and the contractions carefully measured and tabulated for reference in grinding the bore. The jacket is turned down for the first layer of hoops, which are shrunk on in the same manner as the jacket. These are then turned down for the next layer, and so on until the gun is built up. When all the parts are in place, the gun is finish-bored and ground; the grinding is

* Gun Foundry Board Report.

done with a revolving rod, the gun being fixed. The iron head of this rod is covered with lead, and sand is the substance employed, because it is easily washed out of the bore and does not, like emery, enter the steel.

The gun is then finish-turned, rifled, and the breech-screw cut. The rifling edges are rubbed with emery. With the present system (polygroove), the authorities at Elswick do not consider it necessary to pay marked attention to the boring, since the rifling leaves no lands, only edges. But as the trueness of these edges governs the action of the rifling, it would seem that too much attention could not be exercised during the operation of boring.

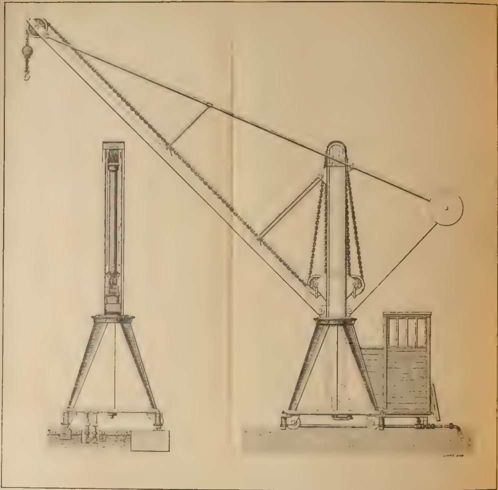
The work of machining and assembling is not carefully done, and not unfrequently a space of $\frac{3}{4}$ of an inch is found between the edges of the hoops.

> "The use made of hydraulic power is probably greater at Elswick than at any other establishment in the world. This might naturally be expected, when it is borne in mind that the world is indebted to Sir William Armstrong for the advance made in this direction.
>
> The system of hydraulics at Elswick extends to all parts of the grounds, reaching all the shops, wharves, and water-front. Pumping-engines are established at convenient intervals, only one working at a time, and the connection of pipes being continuous, the uniform working of the system is established by five or six accumulators with 18-inch rams."*

These accumulators are of 18 tons weight and cost about £20 per ton.

> "The working of the pumping-engine is made automatic. The accumulator nearest to it is slightly more heavily loaded than the others to give a lead in rising to the distant one, and is connected with a steam-regulating valve to act as a governor for adjusting the speed of the engine to the varying demand of the hydraulic machines. The pressure sustained throughout the system is 750 pounds to the square inch. The pipes are usually 5 inches in diameter, the largest being 6 inches.
>
> Hydraulic power is used for the forge and foundry cranes, also for the movable cranes (Plate IV.) which operate along the water-front. For the accommodation of these last, pipes are

* Gun Foundry Board Report.



MOVABLE HYDRAULIC CRANE

done with a revolving rod, the gun being fixed. The iron head of this rod is covered with lead, and sand is the substance employed, because it is easily washed out of the bore and does not, like emery, enter the steel.

The gun is then finish-turned, rifled, and the breech-screw cut. The rifling edges are rubbed with emery. With the present system (polygroove), the authorities at Elswick do not consider it necessary to pay marked attention to the boring, since the rifling leaves no lands, only edges. But as the trueness of these edges governs the action of the rifling, it would seem that too much attention could not be exercised during the operation of boring.

The work of machining and assembling is not carefully done, and not unfrequently a space of ¾ of an inch is found between the edges of the hoops.

> "The use made of hydraulic power is probably greater at Elswick than at any other establishment in the world. This might naturally be expected, when it is borne in mind that the world is indebted to Sir William Armstrong for the advance made in this direction.
>
> The system of hydraulics at Elswick extends to all parts of the grounds, reaching all the shops, wharves, and water-front. Pumping-engines are established at convenient intervals, only one working at a time, and the connection of pipes being continuous, the uniform working of the system is established by five or six accumulators with 18-inch rams."*

These accumulators are of 18 tons weight and cost about £20 per ton.

> "The working of the pumping-engine is made automatic. The accumulator nearest to it is slightly more heavily loaded than the others to give a lead in rising to the distant one, and is connected with a steam-regulating valve to act as a governor for adjusting the speed of the engine to the varying demand of the hydraulic machines. The pressure sustained throughout the system is 750 pounds to the square inch. The pipes are usually 5 inches in diameter, the largest being 6 inches.
>
> Hydraulic power is used for the forge and foundry cranes, also for the movable cranes (Plate IV.) which operate along the water-front. For the accommodation of these last, pipes are

* Gun Foundry Board Report.

run, in junction with the pressure main, with hydrants from 18 to 36 feet apart, from which connection is made with the cranes by means of telescopic tubes. Two or more cranes can thus be brought into operation on any vessel at the water-front."*

They travel on a line of rails by the edge of the quay, so as to accommodate their positions to those of the ships; and the telescopic pipe at the base of the crane affords certain latitude for adjustment.

"On the east end of the wharf are erected large hydraulic shears, worked by a direct-acting hydraulic cylinder, 40-feet stroke, lifting 120 tons. The back leg moves so as to bring the lifting cylinder about 30 feet out; the foot is moved by a screw 50 feet long, with hydraulic engine and gear.

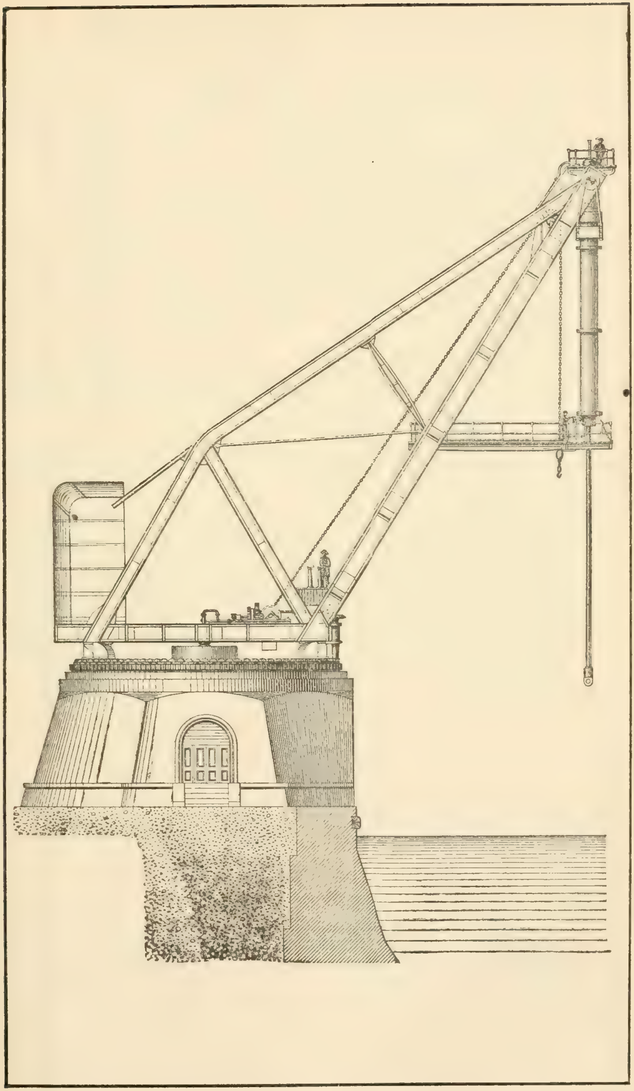
The most notable hydraulic crane that has been produced from these works is the one erected in the Italian naval arsenal at Spezia (Plate V.), which is capable of lifting 160 tons through a range of 40 feet. It is carried upon a ring of line rollers supported by a pedestal of masonry, and the slewing is effected by an hydraulic engine applied to a pinion which gears with a circular rack. The rake of the jib or projection from the centre of rotation is 65 feet, and its height from the quay-level is 105 feet. The crane is counterbalanced on the side opposite to the load." *

As the crane has occasionally to be used for comparatively light loads, a chain is applied for that purpose, and is hauled up by a cupped drum worked by the slewing engine. The direct-acting cylinder employed has a stroke of from 40 to 50 feet, and is suspended in gimbals from the end of the jib; it is fitted with a piston and rod, by which the load is lifted and lowered without the intervention of chains and gearing. The advantages of this plan with regard to safety and simplicity are very great, and the ease and nicety with which the loads can be handled are very striking.

"About the grounds at Elswick, particularly at the approaches to the shops, there are numerous small capstans (Plate VI.) worked by hydraulic engines, which are of great service in hauling heavy loads into or out of shops, and in transporting them from shop to shop." *

The bed-plate carrying the capstan-head and engine is mounted in trunnions in a cast-iron casing, and can be turned over, Figure 2, when access is required to the engine. The casing is bedded in the

*Gun Foundry Board Report.



SPEZIA CRANE.

ground, and very little foundation is needed. A spring-valve at the side, Figure 4, opens and shuts the water-supply.

> "It is almost unnecessary to add that it is at Elswick that the applications for working heavy guns by hydraulic power have been designed and manufactured."*

Sir William advocates replacing all hand-power by hydraulic machinery, and does not believe in having additional hand-mechanism for emergencies; he argues that the question depends upon the probability of the gear getting out of order; that hand-gear is less reliable because it involves so many parts and is necessarily so complicated. Many of these parts are done away with by the use of hydraulic machinery.

> "No foundry or gun factory can be considered efficiently equipped without being provided with arrangements for the plentiful supply of hydraulic power."*

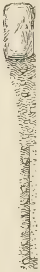
One of the greatest advantages is the facility for the extension of power to any point where additional contrivances may be required for saving time and hand labor.

> "**Woolwich.**—The Royal Gun Factories at Woolwich are of very extensive proportions, and have, in the course of many years, become so well equipped that the present change which has been inaugurated in the system of manufacture of the English gun does not find it unprepared. In a Parliamentary report of 1878-'79, a balance-sheet states the value of all the property and material in the three departments at Woolwich, as follows, viz.:

	£	s.	d.
Land	2,805	9	4
Buildings	97,684	7	11
Machinery	166,110	11	3½
To one year's interest, at 3½ per cent on invested capital, viz.: stores and semi-manufactured articles in stock, April 1, 1878	196,949	15	3
Total	463,550	3	9½

> The capacity for production in the gun factory is stated in 1873-'74 to have been 6000 tons of guns of various calibers per year, or 7500 tons of rough forgings (wrought-iron)." *

* Gun Foundry Board Report.



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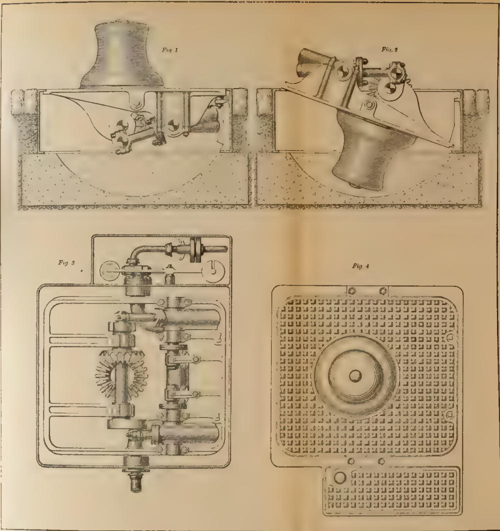


HYDRAULIC CAPSTAN.

The transition state in which the Board found the Woolwich gun factories is due to the change from muzzle-loading to breech-loading, and the substitution of homogeneous metal for the wrought coil. The introduction of steel has supplanted wrought-iron bars, and the rolling and coiling-machines were almost idle. The factories were busy, owing to the additional labor involved in constructing the fittings for the new breech-loading appliances, which require ingenuity and nicety of construction.

"An approximation to the number of tools may be reached by citing the number of boring-machines now in place, viz.:

2 of 72 inches swing, 4 of 51 inches swing, 4 of 42 inches swing,
4 of 36 inches swing, 6 of 30 inches swing, 6 of 24 inches swing,
12 of 20 inches swing,

besides fifty or sixty others of various smaller sizes.

Of other machines there are—

6 planing-machines, 12 shaping-machines, 12 milling-machines,
12 drilling-machines, 12 slotting-machines, 6 radial-machines,
2 dividing-machines.

Of traveling cranes there are—

4 of 60 tons capacity, 6 of 30 tons capacity, 6 of 25 tons capacity,

besides several of from 20 to 9 tons capacity.

The steam-hammers are comprised in the following list:

1 of 40 tons, 1 of 12 tons, 1 of 10 tons, 2 of 7 tons, 2 of 6 tons,

besides many of from 3 to 1 ton.

The steam power in the Royal Gun Factories is supplied by forty boilers of 40 horse-power each. The uniform capacity of boilers is found convenient in case of repairs, when substitutions have to be made. At one point there are assembled twenty-four boilers in one group.

The new feature about the gun factories at Woolwich is the establishment of a foundry for casting steel. The development of this branch of the manufacture is still in its infancy, but already there are several Price's Retort Furnaces in operation, having a total capacity of about 18 tons. The tests of the metal have proved to be very satisfactory, and already some tubes have been accepted for the manufacture of 6-inch steel guns. It is expected, in a very short time, that tubes for 8-inch guns will be produced from this foundry."*

* Gun Foundry Board Report.

DESCRIPTION OF PRICE'S FURNACE. (Plate VII.)

Fig. 1. Plan, through the retort, combustion, and heating chambers.
Fig. 2. Longitudinal section through center of furnace.
Fig. 3. Cross section through combustion chamber.
Fig. 4. Sectional plan through retort chamber at *EE*.
Fig. 5. Elevation, part in section, of retort chamber.

A is a combustion chamber fitted with grate bars in the usual way. *B*, a heating chamber, separated from *A* by the ordinary bridge. *C* is the neck descending into an under-ground flue *D*, leading into an upcast or retort chamber, as it has been designated, *E*. In the center of this chamber *E* is a fire-brick circular pillar *F*, with spaces around, marked *EEEE* (Fig. 1), and on which is placed a cast-iron cylindrical air-vessel *G*, Fig. 2, which is protected by fire-brick.

On this air-vessel *G*, is built a retort *H*, partly of fire-brick, partly of cast-iron. The top of the cast-iron part of the retort is fitted with a hopper *I*, in the throat of which is a damper *J*, worked by a rocking-shaft and lever *K*, from the ground.

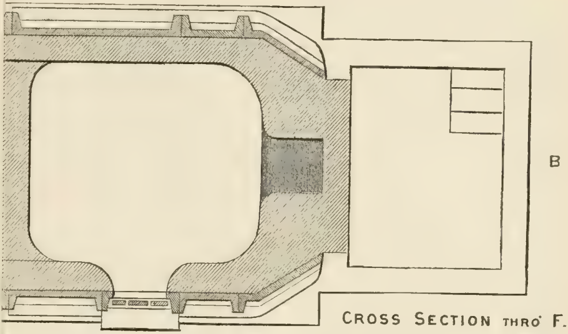
The lower portion of the retort, made of fire-brick, has two necks *LL* ; one leading to the combustion-chamber for the passage of fuel, the other, to the outside of the furnace for the insertion of stoking tools, to force the fuel forward into the combustion-chamber. The entrance of the outer neck is closed by an air-tight door *M*.

The retort-chamber *E* extends to near the top of the retort, where it is closed by brickwork, but is opened at the side by the flue *N*, leading to the stack *O*.

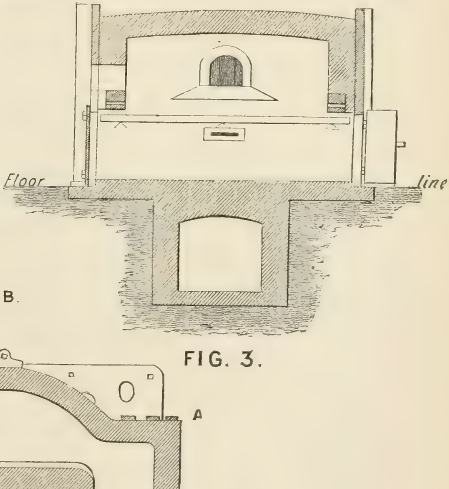
Near the bottom of the chamber *E*, and in line with the center of the circular air-vessel *G*, are pipes *PP*, inserted in the walls of the chamber *E*, passing all around the chamber, as shown in Fig. 4. In front of the inner side of the circuit of pipes, and opening into the chamber *E*, are a number of port-holes *QQQ* (Fig. 4) leading to the space around the pipes *PP*, which space affords scope for expansion and a free circulation of heat. These pipes *PP* are connected with the blast as shown at *E* (Fig. 5) and pass into the central chamber *G*, as shown at *F* (Fig. 2) ; the outlet *R*, from the air-vessel, leads into the ash-pit *S*.

The practice in working is to light a fire on the grate-bars, and generate heat in the usual manner, until the furnace is well heated. The retort is then filled with fuel, and the firing commences from the retort ; by the time the fuel at the top descends to the bottom of the retort, it is well heated, and a continuous supply of heated fuel is then kept up. All raw fuel is from this time supplied to the hopper *I* only, and is let into the retort by the damper without the access of air.

The gases so generated in the combustion-chamber *A* pass over the bridge into the heating chamber *B*, down the neck *C*, into the underground flue *D*, into the retort-chamber *E*, filling the spaces around, and giving up their heat to the circular air-chamber *G*, the retort *H*, and the air-pipes *PP* ; and their residue passes off by way of the flue *N* into the stack *O*, the stored heat being carried back into the furnace by the heated fuel. Combustion is supported by air under pressure from a fan. The air entering, as shown at *E* (Fig. 5) tra-

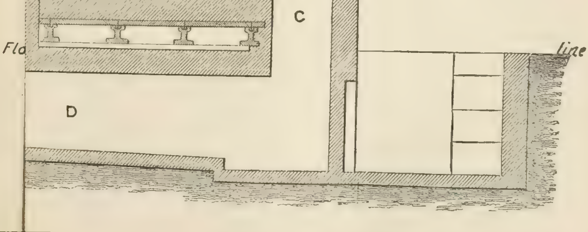


CROSS SECTION THRO' F. F



L SECTION THRO B.B.

FIG. 3.



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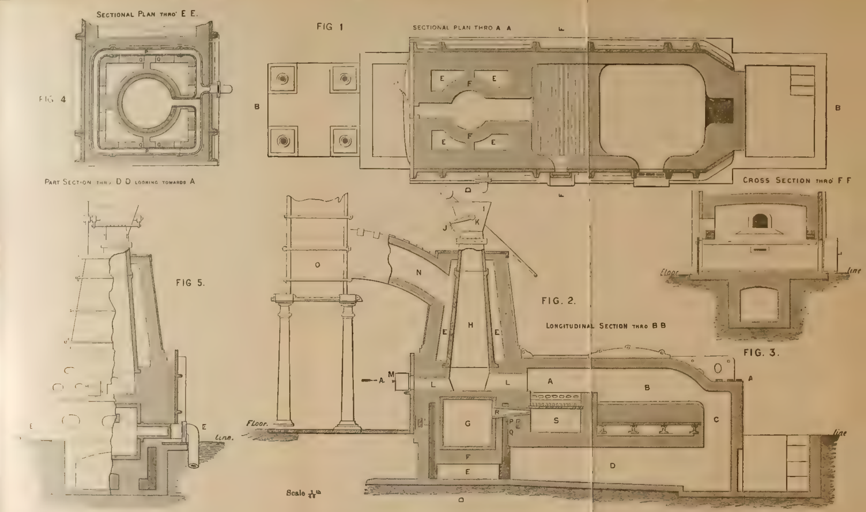


PRICE'S RETORT FURNACE.

verses the entire circuit of pipes, passing into the central air-vessel *G*, out through *R* into the ash-pit *S*, and so up through the grate-bars.

It will thus be seen, from the description, that to some degree the retort furnace embraces in principle that of the regenerative system. In fact, in reply to Dr. Siemens' remarks about the process of making steel at Woolwich: "The apparatus there employed consisted of two things, a furnace, stated to be Price's patent retort furnace, and a process called the open-hearth, but which was in reality as minute a description of the one known by his name as though it had been taken from his instructions,"—Colonel Maitland replied: "In using Price's retort furnace they also used the open-hearth process of Dr. Siemens, and he did not know that there was any idea of claiming originality."

Although this furnace cannot compete with the Siemens regenerative, in the matter of intensity of the temperature to which the heating substances are brought, Mr. Price claims that he avoids the loss which takes place in the gas-producers and regenerative furnace, by raising the temperature of the air, as well as that of the gaseous and fixed constituents of the coal, by the waste heat before it enters the chimney.

In the manufacture of steel at Woolwich, more attention is given to the selection of the charge than to getting rid of the impurities, during the process of making, by mechanical or chemical means. There is very little or no sulphur in the ores employed.

The casting-pit is almost immediately in front of and between the furnaces. Though convenient, such arrangement subjects the men to an undue temperature.

There are three furnaces; one of 12 tons, one of 5 tons, and one of 2 tons. Can cast a 12-ton ingot, from which an 8-ton forging can be made.

> "The 40-ton steam-hammer, which has been used for welding the large coils of wrought-iron used in the late manufacture of the Woolwich gun, is undergoing a change, by having the face of the tup reduced in area in order to be made more efficacious in forging steel ingots. Opportunity is also being taken to reconstruct and repair a portion of the foundation and the anvil-block in order to suit the new conditions. In this connection it may be well to state the cost of this hammer, including that of the four cranes used in connection with it, furnished by Nasmyth, Wilson & Co.:

Hammer	£ 4,980
Cranes and framing	13,500
Expended in department	10,915
Inspector of works, charges for building foundations, furnaces, &c	9,245
Floor-plates	3,683
	42,323" *

In preparing its foundation, an excavation was made to a depth of 20 feet. Piles were then driven 25 feet into the gravel. On a level with and about the head of the piles, 4 feet of concrete was laid. Upon this, layers of 50-ton castings were placed to form a bed for the anvil-block of 100 tons. Between the layers of iron castings, a sandwich of oak timber, about 12 feet square and 2 feet long, was placed on end.

A Maillard Testing Machine, manufactured at Le Creusot, is employed.

Trepanning (boring around a core) is much used at Woolwich for all calibers, and is considered very economical. The core is sometimes utilized for guns of small caliber.

The shrinkage and tempering pits are not together, and consequently require separate cranes. The enormous crane over the tempering pit was constructed here, and its great power is not known. To prepare the tempering plant, at a distance of 7 feet from each other, two large cylindrical pits were dug, the bottom of each being laid with 3 feet of concrete. Into the larger, an iron cylinder was inserted and lined with fire-brick, as a furnace for heating the tubes. The smaller contains two iron cylinders, one within the other. The inner, 32 feet, 6 inches deep, and 6 feet in diameter, contains the oil; the outer, water. The tempering department is under the charge of Mr. George Ede, who has thus described the process employed:

A block, or tube, of mild cast-steel (or steel containing a smaller proportion of carbon than ordinary cast-steel) is lifted by a powerful crane and placed in a perpendicular position in an upright furnace; an iron coil about 6 inches in depth and about one inch larger in diameter than that of the tube, is placed upon the fire-bars, at the bottom of the furnace, for the tube to rest upon; beneath this iron coil is placed a piece of plate-iron to prevent the cold air, as it passes through the bars, coming in contact with the extreme end of the tube, and in order to obtain a uniform temperature at the extreme end of the tube this iron coil is filled with wood ashes. This is done while heating the furnace to a red heat with refuse wood previous to putting the tube into the furnace. After the tube is placed, its bottom end is surrounded with short blocks of

* Gun Foundry Board Report.

wood. When the extreme end has acquired a low red heat, the damper is lifted and the tube entirely surrounded with longer pieces of wood, thrown in from the top. It is then slowly heated to a bright red, by the combustion of the fuel. Wood is used in preference to coal or coke, an account of its purity ; it is not so likely to degrade the steel, and has a tendency to give pliability without diminishing hardness. When the tube arrives at a bright red heat the vent is closed for a few minutes to give the steel time to soak and so receive a uniform temperature throughout. This is necessary to keep the tube straight ; and it will acquire a more uniform temper. When ready, the traveling crane is brought over the furnace, the cover removed and the crane-tongs hooked to the tube. These are so constructed that the heavier the weight, the tighter they grip, but it is found necessary to turn a small collar on the end of the tube to prevent the tongs slipping. The tube is drawn out of the furnace, swung over the oil tank and lowered rapidly into it. This tank is of iron and contains several hundred gallons of rapeseed oil. The heated tube, in entering the oil, fires the surface, but this is extinguished by shutting the covers of the tank as soon as the tube is immersed. A water space surrounds the tank and cools the oil. As the water becomes heated it is drawn off at the top, a continuous supply running in at the bottom. This stream of water causes the heat to be gradually taken from the mass, and the whole cools uniformly in about twelve hours.

OPERATIONS TO BE PERFORMED AND PLANT REQUIRED FOR THE MANUFACTURE OF STEEL B. L. GUNS, AS PRACTISED AT WOOLWICH.

Condition of Material.	Operation to be Performed.	Plant or Machine Required.
Block for tube ; forging as received from contractor.	Test pieces to be cut off.	Lathes and slotting-machines. (1.)
Test pieces.	Tempering.	Small furnace and oil-bath with pyrometer and batteries.
Test pieces.	Testing (tensile).	Testing-machine.
Test pieces.	Testing (bending).	Bending-machine, with press or block.
Block for tube.	Rough-boring for tempering.	Boring-machines (horizontal). (2.)
Block for tube.	Rough-turning and tempering.	Lathes.
Tube.	Tempering.	Vertical furnace, oil-bath, and overhead crane. (3.)
Forging for hoops, trunnion-pieces, breech-screws, etc., as from contractors.	Similar operations to the above.	As above, except for boring, which generally would be done in lathes with large chuck-plates.

OPERATIONS TO BE PERFORMED, &c.—Continued.

Condition of Material.	Operation to be Performed.	Plant or Machine Required.
Tube, trunnion-piece, and hoops, tempered.	Finish-turning and boring ready for shrinkage.	Machines similar to the above.
Several details finished, ready for shrinkage.	Shrinking up.	Furnace or open grate with pit, crane, water supply, and gas service. (4.)
The built-up piece.	Finish-boring and chambering.	Horizontal boring-machine.
The built-up piece.	Finish-turning.	Heavy lathes.
The built-up piece.	Rifling.	Rifling-machine.
The built-up piece.	Preparation and fitting of the breech-action.	Planing-machine. Shaping-machine. Milling-machine. Drilling-machine. Slotting-machine. (5.)
The built-up piece.	Examination preparatory to proof.	Gauges, micrometers, impression-takers, inside and outside callipers, etc.
The built-up piece.	Proving.	Proof carriage, butt, and ammunition.
Finished gun.	Sighting and manufacture of sights.	Radial drilling-machines. Milling-machines. Shaping-machines. Drilling-machines. Slotting-machines. Dividing-machines. (6.)

REFERENCES:

1. Sizes of machines depend upon dimensions of gun.

2. Worm gear arrangements for boring are preferred in the Royal Gun Factory.

3. Size of plant depends upon extreme dimensions of guns.

4. Size of plant depends upon dimensions of gun. As a rule, the gun is not entirely shrunk up in one operation. It is usual to prepare the seats for the several layers of hoops after each cycle of shrinkage, by turning the partly finished gun in a lathe, so as to secure as far as possible uniformity of truth throughout. The number of removals of the gun from the pit to the turnery depends, of course, upon the design and construction adopted.

5. In connection with these operations a large amount of hand labor is required to secure the necessary adjustment.

6. A large amount of hand labor is also involved in connection with these operations.

The plant at Woolwich, because of its transition state, contains very little worthy of imitation in planning the erection of gun factories in the United States.

"**Steel Manufacturers.**—While considering the sources from which the armament of England is supplied, the steel manufacturers who provide the tubes, jackets, and hoops should be named. They are:

Thomas Firth & Sons, Sheffield.
Charles Cammell & Co., Sheffield.
Vickers, Sons & Co., Sheffield.
Sir Joseph Whitworth & Co., Manchester.

A foundry for steel casting is now being added to the plant at Elswick.

Heretofore the gun-carriages for both the army and navy have been provided from the gun-carriage department at Woolwich on their own designs; but since the adoption of the Vavasseur gun-carriage by the Admiralty, the works at Elswick, as well as the London Ordnance Works of Mr. Vavasseur, have been called upon to supplement Woolwich in the production of a supply of these carriages. At the present time the Admiralty have on hand, or under construction, about 450 of them suited for all calibers of guns."*

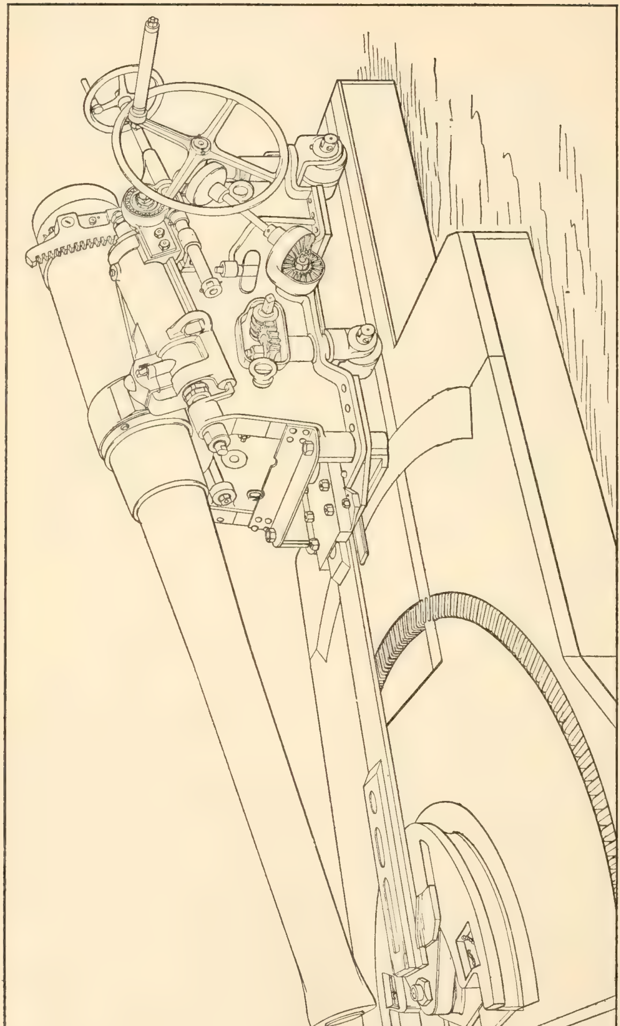
These carriages (Plates VIII. to XIV.) are composed of the following principal parts:

Carriage,	Running in and out gear,
Slide,	Compressor,
Training-gear,	Adapting-slide for revolving purposes.
Elevating-gear,	

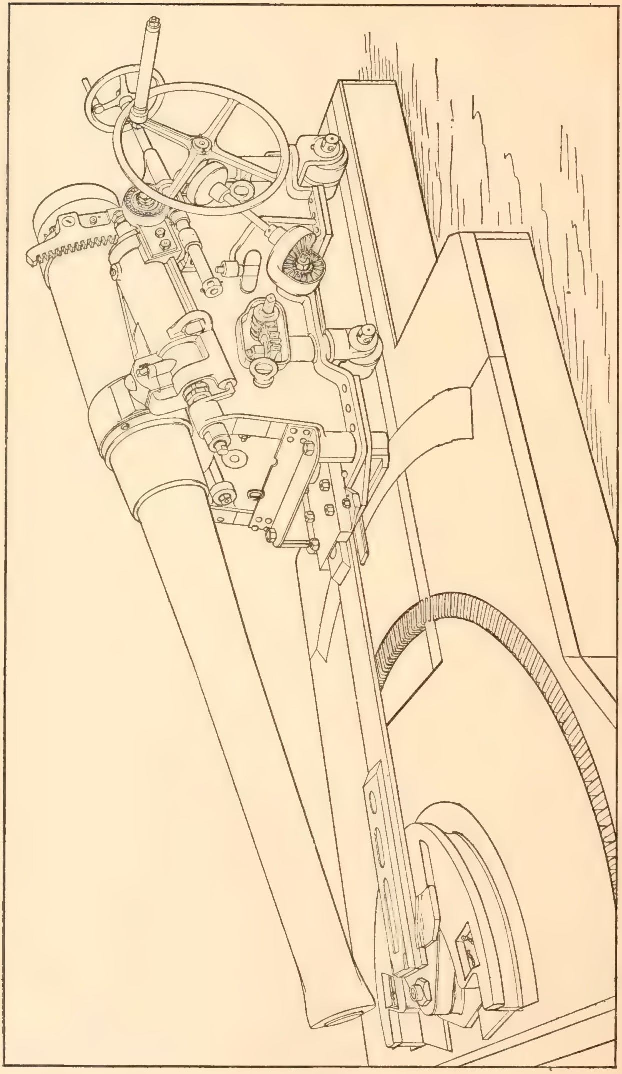
The carriage may be divided into three parts; the part carrying the gun, and the two compressor cylinders fixed to it. The two brackets of the carriage and the transom joining them are of one piece, of either cast or forged steel. The width of the bracket is that necessary for the trunnion-bearings and for the proper attachment of the cap-squares. The trunnion-bearings are kept as near the top of the slide as possible, and the transom just clears the trunnion-hoop when the gun is at its maximum elevation or depression.

The compressor cylinders are made of forged steel. The front ends fit into recesses provided for them in the carriage, and are secured to it by nuts let into recesses; when thus fixed, they form a continuation of the brackets, and rest on the tops of the girders forming the slide. The rear ends have projecting pieces forged to them, and grooves are cut in these which fit over the girders of the slide. The recesses fit corresponding projections formed on the top edges of the girders. There are similar grooves and recesses on the carriage. These, with the front clamp, so arranged that a lip comes under the projecting part of the front racer, keep it from lifting or jumping when the gun is fired.

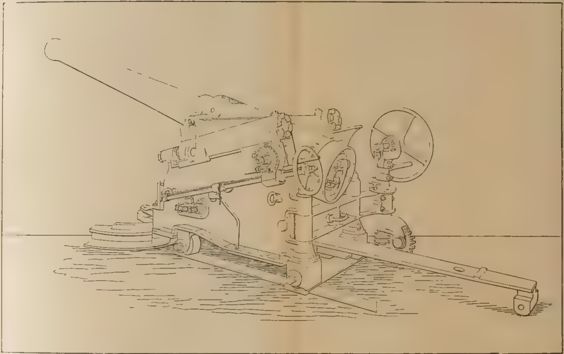
* Gun Foundry Board Report.



VAVASSEUR 6-INCH HYDRAULIC CARRIAGE, WITH SLIDE.

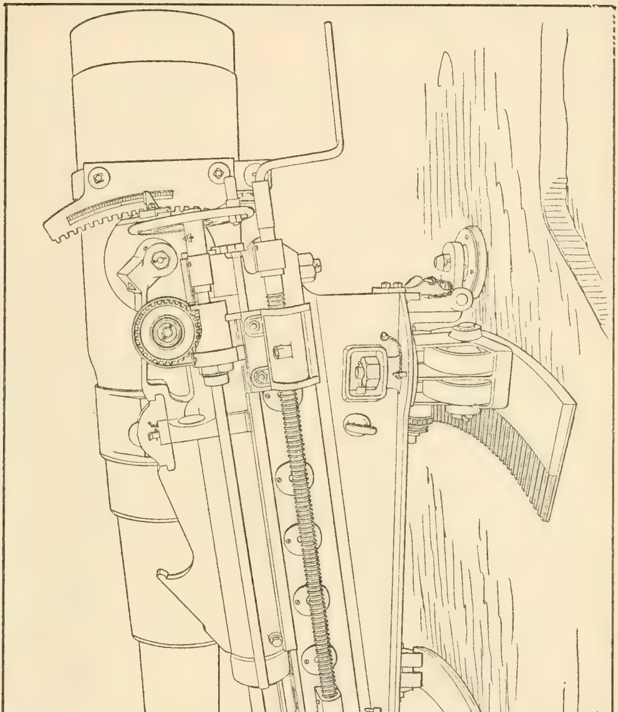


VAVASSEUR 6-INCH HYDRAULIC CARRIAGE, WITH SLIDE.

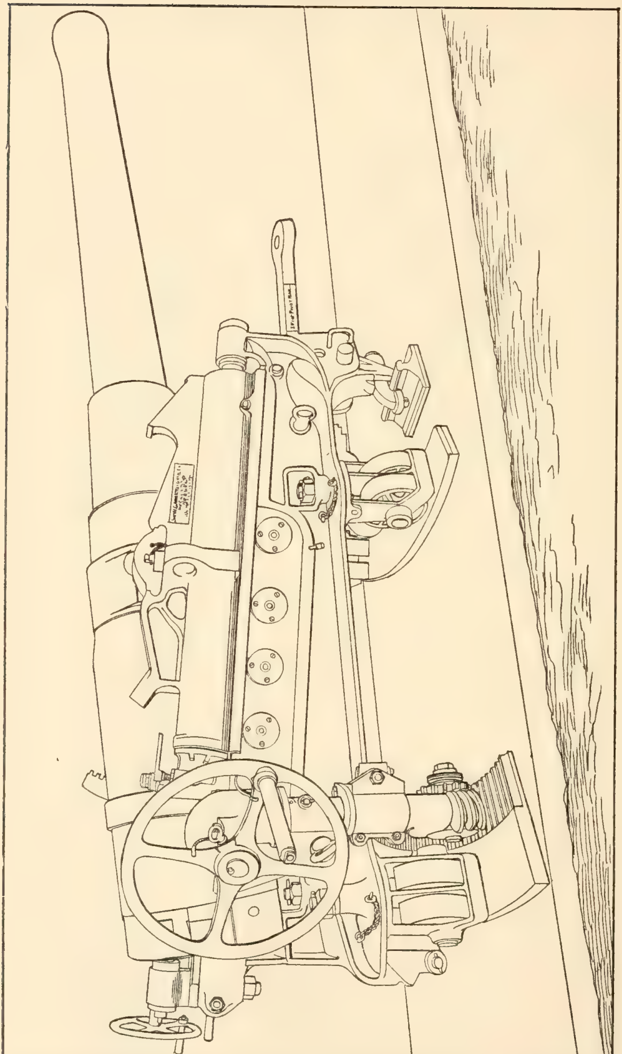


VAVASSEUR CARRIAGE, WITH SLIDE FOR HOUSING

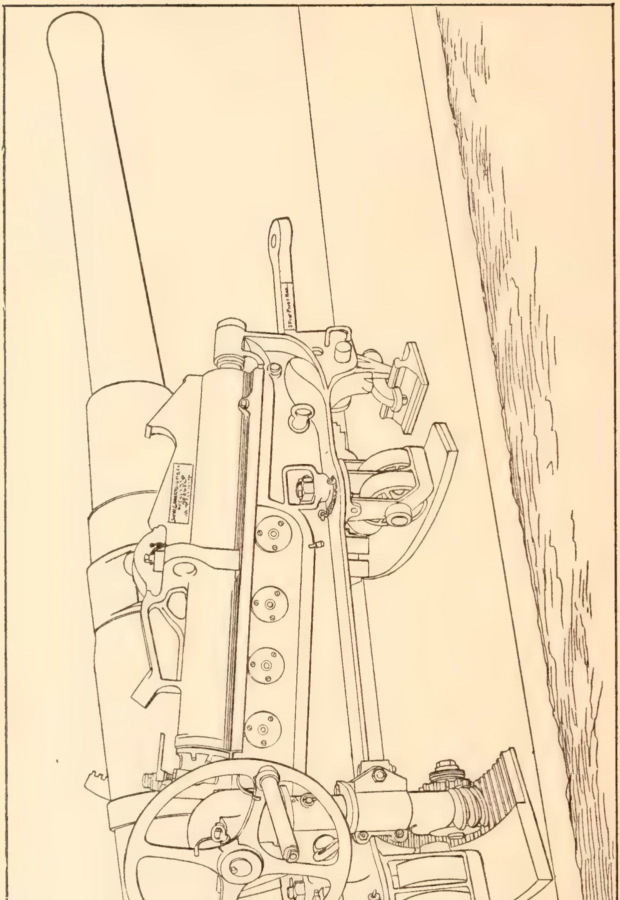
PLATE X.



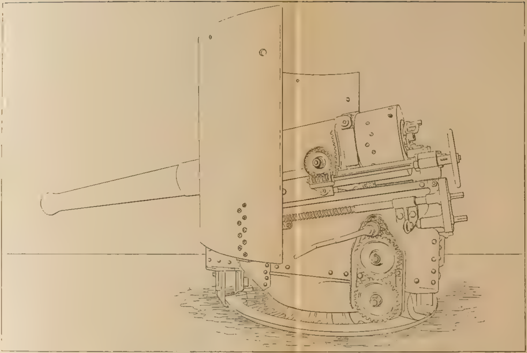
VAVASSEUR 8-INCH HYDRAULIC CARRIAGE, WITH SLIDE.



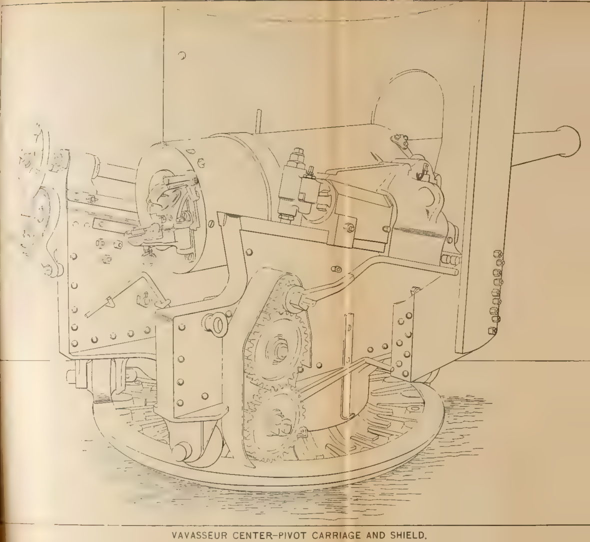
VAVASSEUR 8-INCH HYDRAULIC CARRIAGE, WITH SLIDE.



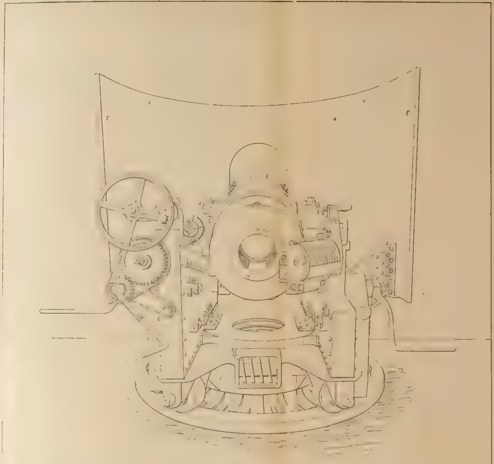
VAVASSEUR 8-INCH HYDRAULIC CARRIAGE, WITH SLIDE.



VAVASSEUR CENTER-PIVOT CARRIAGE AND SHIELD.



VAVASSEUR CENTER-PIVOT CARRIAGE AND SHIELD.



VAVASSEUR CENTER-PIVOT CARRIAGE AND SHIELD.

This method of attaching the compressor cylinders allows them to be removed readily in case of accident, and without dismounting the gun.

The girders forming the sides of the slide are each composed of two plates. The bolt for connecting the pivot-link to slide passes through the front end. The projection along the top edge fits into the recesses, already referred to, on the carriage and compressor cylinders. Towards the rear end of the slide, between each pair of plates, rollers project slightly above the top, and as the gun and carriage recoil, they run on to them, so that when the gun is brought up at the end of recoil, the carriage is on the rollers and running out. The plates forming the girders are jagged over the front and rear transoms and attached to them by rivets passing through projecting pieces cast on to receive them.

The front and rear transoms, or roller brackets of slide, are made of cast-steel, with flanges or ribs reaching down far enough to embrace both edges of the front and rear racers, and are machined to fit them accurately. Between these flanges, which are braced together, are the training rollers, kept open at the ends for cleaning, the openings closed by a sliding plate. This plate scrapes the tops of the racers, and keeps the roller path clean and free from obstructions.

Midway between the front and rear rollers are clamps, clipping the racers. They work through openings cut in the flanges of the brackets, and are worked from the rear end of slide by means of a capstan-head. By these, the slide can be fixed in any desired position, or sufficient friction may be given to prevent the slide from moving when the ship is rolling.

The training-rack is made up of two widths cast together, and with the pitch divided so as to reduce as much as possible the play between the teeth of the pinions and rack.

The pinions are connected with a worm-wheel (one on each side), which is driven by a worm fixed to a vertical shaft. The shaft is driven by a pair of bevel wheels placed at a convenient height for the men to work to the best advantage.

The gun can be trained either from the handle or from the hand-wheel at the rear of slide—this is arranged for slow training, and the power is doubled by means of spur gearing. If the gun is to be trained only from the handle, two of the three pairs of wheels could be omitted. The rack-pinions and worm-wheel run loose on a pin carried in a bracket; by taking out this pin they can easily be removed for cleaning. The rest of the gear is carried in one bracket, by removing which, the whole comes away.

The elevating-gear consists of a rack rigidly secured to a ring shrunk over the breech of the gun—the wheel working this is carried in a lug forged on the top of the rear end of the left hand compressor-cylinder, and is driven by a worm-wheel and worm carried on the cylinder. The worm is driven by a grooved shaft, which slides through it, worked from the end of the slide by a hand-wheel. This arrangement allows the gun to be moved up to the moment of firing.

The gun is run in and out when necessary by hand, by means of a screw carried in bearings on the exterior of the left hand of the slide; and by an

ingenious method of half-screwed nuts and bevels, the gear is made self-adjusting. The screw is driven from the side of the carriage by means of a pair of bevel wheels.

The compressor-cylinders form part of the carriage and have been referred to; they are rifled, each with two helical grooves and are connected at the rear by a pipe. A recess or groove is turned on the circumference of the pistons, into which a gun-metal ring or valve is fitted, having two projections which enter the helical grooves of the cylinders. Across each piston and valve two or more passages are cut, making direct communication across the piston.

The piston-rods of each cylinder are attached to brackets secured one at the front and the other at the rear end of the slide. Means are provided by which the pistons can be so rotated that the passages in the pistons and valves can be placed in any desired position in relation to each other and that the piston passages can be closed at any desired point.

The piston-rods being attached one to the front and the other to the rear end of the slide, it is evident that as the cylinders move during recoil, one piston-rod is being withdrawn from one cylinder, while the other piston-rod is being pushed into the other cylinder. The liquid displaced by one rod flows through the pipe and exactly compensates the deficiency caused by the withdrawal of the other. This arrangement allows both cylinders and connecting-pipe to be kept full of liquid, and entirely suppresses all air spaces.

To control the movement of the gun in running out, a valve is placed in the connecting-pipe. It is evident that when this valve is closed, no water can pass from one cylinder to the other, and the carriage cannot run out, as any movement would tend to force the rod into a cylinder full of liquid. This valve is so arranged that should the cock be closed by mistake or design, no harm could be done, as it does not interfere with the recoil of the gun, but it must be opened before the gun can be run out.

Experiments with a 6-inch carriage show that the recoil is practically constant whatever the charge of powder. With charges varying from 20 to 35 pounds, the difference was only 1.7 inches in the total recoil of 34 inches; and with charges varying from 25 to 35 pounds, a difference of only .6 inch in a total recoil of 20 inches. By making the cylinders of adequate strength, the recoil of any gun can be controlled as desired. In the designs, three times the caliber of the gun is the proposed length of recoil, as with this length, the slide can be made so as not to project beyond the breech of the gun when run out. Beyond this it seems unnecessary to go in the direction of shortening the slide. It was further shown that the maximum pressure in the cylinders is reached gradually, easily, and without shock, and that there is very little, if any, tendency of the carriage to jump or lift from the racers when fired.

The arrangements for housing, pivoting, and shielding are very

simple and compact. The simplicity, perfect working power, and limited space are three very great elements in favor of these carriages for naval use. The following table of dimensions particularly points out the small space occupied in comparison to other carriages:

Size of Gun	6-inch.	7-inch.	8-inch.	9-inch.	10-inch.
Length of slide	6′ 3″	7′ 0″	7′ 7″	8′ 4″	9′ 5″
From front end of slide to inside of ship	2 1	2 6	3 2	3 4	3 6
From inside of ship to rear end of slide	8 4	9 6	10 9	11 8	12 11
Height of deck to center of trunnion	3 5	3 6	3 7½	3 11	4 2
From top of slide to center of trunnion	1 4	1 5	1 6½	1 9	1 11
From center of cylinder to center of trunnion	9½	10½	11½	1 1	1 3
Height from deck to underside of slide	1 4	1 3	1 2	1 2	1 2
Height from deck to port-sill	2 6	2 5	2 4	2 7	2 5
Height of port at inside of ship	2 11	2 10	3 1	3 4	3 10
Height for elevation	12°	10°	10°	10°	10°
Height for depression	5°	5°	5°	5°	5°
Width of port at inside of ship for angle of training 90°	2′ 9″	3′ 6″	4′ 7″	5′ 3″	5′ 7″
Minimum width of port	1 10	2 0	2 2	2 9	3 5
Length of recoil	1 6	1 9	2 0	2 3	2 6
Width of slide	3 3	3 7	4 2	4 10	5 4
Extreme width over gear	5 3	5 9	7 1	7 8	8 2
Radius of training-rack	7 0	8 3	9 7	10 6	11 8
Estimated stress on pivot, if used	56 T.	70 T.	80 T.	99 T.	118 T.
Weight of carriage and slide	40 cwt.	60 cwt.	80 cwt.	120 cwt.	160 cwt.

The eminently successful experiments that have been made with the Vavasseur carriages show them to be without an equal.

"CONDITION OF STEEL MANUFACTURE.

The Board visited the following works, viz.:
Thomas Firth & Sons, Sheffield.
Sir John Brown & Co., Sheffield.
Charles Cammell & Co., Sheffield.
Vickers, Sons & Co., Sheffield.
Sir Henry Bessemer, Sheffield.
Sir Joseph Whitworth & Co., Manchester.
Bolckow, Vaughan & Co., Eston."*

The smelting of iron is one of the oldest industries of Sheffield. Foreign iron began to be used here more than 300 years ago, and as it came more into use for manufacturing purposes, the smelting ceased in the town. Messrs. John Brown & Co. were the first to re-introduce it, about 25 years ago.

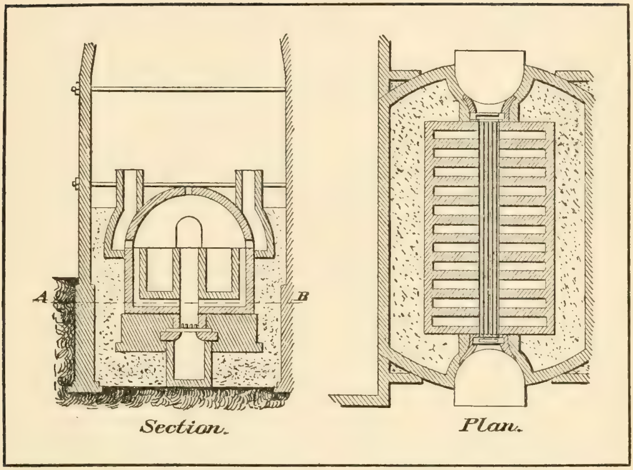
Spiegeleisen is also made in considerable quantities, chiefly from manganiferous ores imported from Spain, and is extensively used in the manufacture of crucible and Bessemer steel. It was imported from Germany until about 10 years ago, when Messrs. Brown & Co. commenced its manufacture. The home product is now considered superior. The manufacture of steel also dates back to a remote period: it was then made in smelting iron with wood. The best iron for steel purposes is that produced from the Swedish mines. Russian iron has long been held in high repute, and that from Spain is also extensively used.

Thomas Firth & Sons.—Crucible steel making is very carefully conducted here and the product is of a very high standard. The Swedish bar-iron of 3 inches by ½ inch section, is first converted in the cementation furnace with a coke cement, the charge being finished with sand and white ashes from the ash-pans.

Lieutenant Constantine Chase, U. S. A., in his "Metallurgy of Iron," gives the following description of the cementation furnace:

The cementation of bar iron is effected in large rectangular chests of refractory brick, two in number, in a furnace with a flattened arch. Each of these chests must be heated as uniformly as possible and carried to a high, but inferior, temperature to that which will fuse the metal. To this end the chests rest upon separated transverse piers of refractory brick about 10 inches thick. The intervals between the piers form a series of flues underneath them. The two chests placed parallel in the direction of the length of the oven are about

* Gun Foundry Board Report.



CEMENTATION FURNACE.

two feet apart: the interval which separates them is divided, by means of the piers which support them, into flues corresponding to those which pass underneath. Refractory walls rise around the two chests so as to form a rectangular chamber, and piers divide all the space between the walls and the chests into flues. A cylindrical arch of refractory brick covers the whole. It is furnished at each end with a door large enough for a man to pass in to charge the iron or take out the steel. These doors, during cementation, are luted with clay.

Over the arch rest, on each side, three chimneys placed at regular intervals, which suck up the burnt gases at the break of the arch, and discharge them under a wide conical cupola of great height. The oven is heated by a grate which extends the whole length of the chests: it has a solid door at each end, which is ordinarily closed, only opened for the introduction of a fresh charge of fuel.

In charging, over the bottom of the chest, a bed of cement is first spread and well beaten down. Upon this bed is placed a layer of bars, arranged flatwise, taking care they do not touch each other. Between these bars and above is spread another layer of cement, then a second layer of bars, and so on until the chest is filled, giving greater thickness to the last layer of cement. The chests being charged and rendered impermeable to air, the furnace is closed and the fire lighted. The temperature of the furnace should be uniformly maintained at a lively red heat during the time, which varies from seven to ten days, according to the degree of carbonization sought. This being reached, the fire

is drawn and the furnace left to cool, which generally requires several days, during which the carbonization continues and becomes more uniform.

The furnaces in Sheffield vary in size from 15 to 30 tons; the cementation is more uniform and less expensive in the smaller furnaces.

The crucibles are made of clay found in the neighborhood. This is trodden into a paste with the naked feet and afterwards tossed and kneaded by hand. The machine-moulded crucibles are not so good, as fragments of stone and other hard substances cannot be detected. These and air-cells would be fatal to the crucible, causing it to blow or leak. The crucibles are formed on hand-moulds and slowly dried on shelves. The bottoms are strengthened with, and the covers are made of, a composition of broken-up crucibles.

Lieutenant Chase continues:

The furnaces used for the fusion are natural draft, small rectangular stacks with grate and ash-pit, each provided with a special flue which conducts the gases into a high chimney common to the whole row of furnaces, the floor of which is at the level of the ground. Each of them is closed by a lid of refractory brick enclosed in a frame of iron and furnished with a handle. The ash-pits open into a cellar where they can be watched. In each fire, and on disks of refractory earth are placed two or four crucibles, each containing from 36 to 60 pounds of steel. The crucibles are arranged in the furnace, surrounded with coke and then the stack is filled with fresh coke. The first heat raises the temperature of the crucible and chimney. At the end of about 20 minutes the crucibles are charged, the covers luted on with care and the temperature rapidly raised. The fusion lasts from 3¼ to 5½ hours. The crucible is cleared from slaggy masses by stirring and is lifted out of the furnace (when ready to cast) with a pair of curved-nosed tongs. Fusion by coke is very expensive. Furnaces heated by gas on the Siemens system, in which as many as 24 crucibles may be placed, permit of obtaining much higher temperatures and consume much less fuel.

The steel is cast in iron moulds washed with fire-clay. An open-hearth plant is also being erected.

Before forging, all bad spots are chiselled out, on the theory that they will, otherwise, be forced into the block and retained in hammering. Marked attention is paid to this operation.

The steam-hammer has a tup of 25 tons, a stroke of 13½ feet, and a steam pressure of 60 pounds. In this forge, Siemens furnaces are employed for re-heating.

In tempering, the blocks are raised to a temperature of from 1200° to 1500°. If the tests show too great hardness and too little elastic limit, annealing is resorted to at a much less heat.

Messrs. Firth and Sons have in their shops, among others, two of the finest tools in England: one, a boring machine manufactured by Greenwood and Batley, of Leeds; the other, a turning lathe, manufactured by Hulse and Co., of Manchester.

Vickers, Sons and Company.—The River Don Works are said to have been the first to commence in England the manufacture of steel castings in shapes, and has the credit of introducing cast-steel tires and heavy steel forgings. Cast-steel bells are a specialty and a very large production.

In regard to the process of producing steel, on the authority of the Superintendent of the Royal Gun Factories, in addition to crucibles, it is produced by the Martin-Siemens process. Mr. Vickers took exception to this statement and said Colonel Maitland had never been in their works, and consequently did not know how their steel was produced. They had adopted Siemens furnaces for their crucibles years ago, and had gradually used his subsequent patents, and, with additions to their own, had made a most complete process. If he were asked to give a name to it, he should call it either the Siemens-Vickers or the Vickers-Siemens process. He considered he had been able to produce by his furnace such steel as had never been made before in a Siemens furnace. Mr. Vickers considers open-hearth superior to crucible steel because less subject to the fluctuations of manipulation.

The steam-hammer has a tup of 15 tons, a stroke of 10 feet, and a steam pressure of 60 pounds. Unusual power, for so light a tup, is claimed in the peculiar steam connections, altered and fitted at the Works. An hydraulic forging-press is under construction.

Hoops or frettes 22 inches wide and having an exterior diameter of 62¾ inches, are rolled upon a tire-rolling machine; the tests have shown the method to be an excellent one.

Tempering and annealing are practiced, and the shops contain fine tools for machining and assembling the largest engine shafts required.

Sir John Brown and Company.—The Atlas Works are among the largest in Sheffield and manufacture iron and steel of every variety and shape. The fabrication of compound armor is a very extensive industry, and the rolls by which the plates are formed are of immense proportions. There are two 12-ton open-hearth furnaces and two 15-ton Bessemer converters. The steam-hammer has a tup of 20 tons.

The plant for the manufacture of steel-faced armor is very complete, and is the result of a careful and intelligent development, involving many patents. The tools include presses for bending, lathes for shaping, and a planer of 170 tons, made by Thomas Shanks and Company, of Glasgow.

To show the progress and to remove wrong impressions of the methods employed in the production of this armor, some of the principal patents are cited.

In 1869, John D. Ellis was granted a patent covering the following claimed invention:

The width of rolled armor-plates has hitherto been greatly restricted by the difficulty of suitably heating a wide pile, and of perfectly expelling therefrom in the rolling, the cinder or slag, which, while such pile is being heated, accumulates in the space between the separate moulds constituting it. I overcame these difficulties, and roll armor-plates of great width from comparatively narrow piles, by rolling the pile first to the full breadth and then to the full length required, or first partly to the breadth, then partly to the length, and so on alternately, until the desired dimensions are obtained, in lieu of rolling in one direction as hitherto practised.

In 1877, another patent was granted, covering the following:

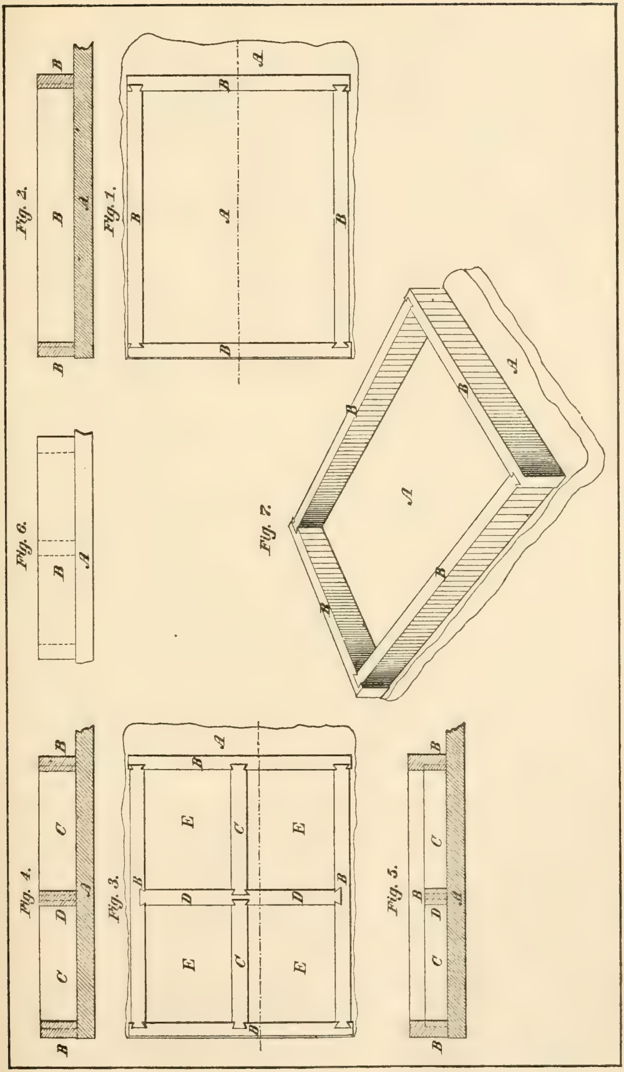
My invention has for its object, the hardening of the surface of armor-plates, and consists in making the plates either entirely of the best soft iron, such as is now used in the manufacture of armor-plates, or of the same iron with a portion of a more steely quality on either one or both surfaces, and afterwards cementing or converting the surface or surfaces by introducing the plate into a converting-furnace, and treating it with charcoal or other material ordinarily used in the converting process. This conversion of the surfaces may be effected either before the plate is rolled to the required size or after it is finished.

In 1878, he obtained another, as follows:

My invention of "Improvements in the Manufacture of Armor-Plates" has for its object an increased facility in the manufacture of armor-plates composed of iron and steel, combined or united; and, also, in the subsequent planing and finishing of the edges of such plates. My invention (Plate XV.) consists in making a plate A, of the usual wrought-iron, and afterwards fixing thereon, round the edges of the same, a wrought-iron frame B, of such width as may be required to enclose the steel to be added to the wrought-iron plate.

The height or depth, and also the length and breadth, of the frame B will be varied as required to suit the dimensions of the finished plate of combined iron and steel.

This frame is or may be fixed together in its parts before heating in the furnace by dovetailing, as shown in the figures, or the parts may be otherwise fixed together.



MANUFACTURE OF COMPOUND ARMOR—ELLIS' PATENT.

Long bars CC, and transverse bars DD, may be fitted into the frame B by dovetailing, as shown in figure 3 (or they may be otherwise fitted), so as to divide the enclosure within the frame, and form additional cells EE, for the reception of molten steel, in order that the steel in the finished plate may be intersected by the said bars of wrought-iron.

In figure 3, the bars CC and DD are so arranged as to form four cells for the steel to be poured into, but this number may be varied.

In figure 4, the bars CC and DD are shown of the same height or depth as the frame B; and in figure 5, they are shown of less height or depth than the frame.

In figure 3, also, the cells EE are shown as rectangular, but they may be otherwise formed so long as the bars or partitions CC and DD are arranged in such a manner as to divide into suitable cells the surface of the plate enclosed within the frame B, and thereby correspondingly divide the steel portions of the compound plate. This plate with its frame thereon is then to be placed in an ordinary plate-heating furnace and heated to a welding heat, and a suitable quantity of molten steel, made by the Bessemer or other process, poured on the surface of the plate, thereby filling the enclosure within the wrought-iron frame with steel of the depth or thickness required. With reference to the mode of manufacturing the entire armor-plate, the iron portion thereof is made by the ordinary method of manufacturing wrought-iron armor-plates, and the bars forming the walls both of the frame and the cells are composed of a similar quality of iron. After the iron plate, with the frame or framing and bars, has been heated in the furnace (which only differs in size from the ordinary reverberating iron-heating furnace) the steel may be poured on while the plate is in the furnace; but it is preferred to take the iron plate with its frame, or frame and bars, from the furnace, and then pour the steel on to it. The combined iron and steel plate is then allowed to cool and solidify, after which it is re-heated in an ordinary furnace and reduced to the thickness required either by forging, pressing, or rolling, or by all or any of these processes in combination.

In finishing the compound plate, the outside frame or framing may be either removed entirely or so as to leave a portion of it on the edges of the said plate.

In some cases also it may be found desirable to insert longitudinally or transversely, or both, bars of wrought-iron, in order that the same may intersect the steel, for the purpose of reducing the lengths of the cracks in the steel when penetrated by shot.

By manufacturing in the manner above described armor-plates of iron and steel in combination, the result is the production of a plate in which the steel is capable of presenting the greatest resistance to the penetration of shot, and the iron has the least liability to fracture or cracking, the combination of the two in the compound plate affording the best means of protection either for ships or other purposes. The advantage of the wrought-iron frame (when that is left on the plate) consists also in the facility which it affords in planing and slotting the edges.

In 1879, Mr. Ellis toughened and strengthened his rolls by cementation, and claimed that by so doing he obtained a roll with a surface much harder than could be produced in any other way.

Fig. 1.

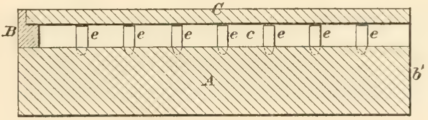


Fig. 2.

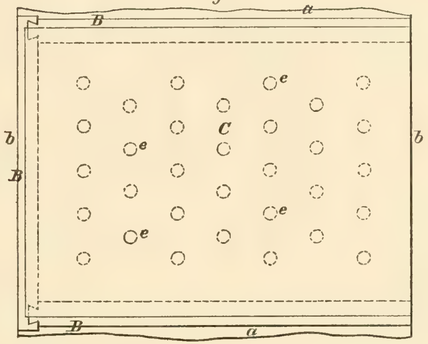
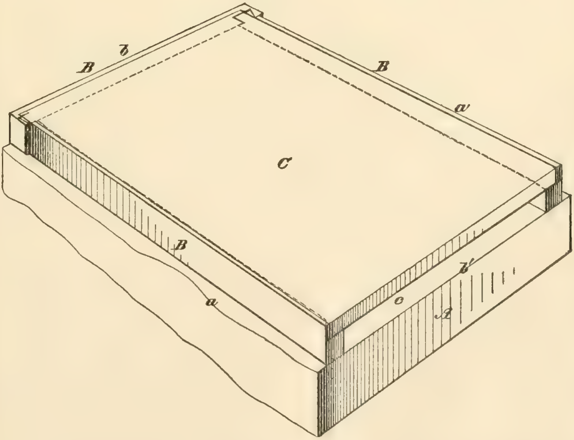


Fig. 3.



MANUFACTURE OF COMPOUND-ARMOR—ELLIS' PATENT.

In 1880, another patent was granted:

My said invention relates to improvements in the manufacture of armor-plates composed of iron and steel united or combined, by means of which improvements armor-plates of this description are obtained sounder and more reliable than heretofore, and otherwise of a superior quality to plates produced by other methods.

Figure 1 (Plate XVI.) represents a vertical section of a wrought-iron plate, with a wrought-iron or steel frame and steel-face plate attached to it in readiness for the reception of molten steel to be introduced into the space formed between the two plates and the frame; figure 2 is a plan corresponding to figure 1, and figure 3 is a perspective view also illustrating the same arrangements.

A is a plate made of the usual quality of armor-plate iron.

B is a frame made of wrought-iron or steel fixed on the iron plate on two sides *aa*, and one end *b*. The height or depth and also the length and breadth of the frame B will be varied as required to suit the dimensions of the finished plate of combined iron and steel.

C is a steel plate made from an ingot either by the Bessemer, Siemens, or any other system (of a suitable quality to resist shot), and worked either by hammering or rolling, or both; it is fitted on the frame B by bolts passing through the frame B, and screwed or otherwise fastened on to the wrought-iron plate A, thickness or distance-pieces of steel, *ee*, figures 1, 2, being placed between the iron plate A and the steel plate C to keep them apart when in the fire.

With reference to the mode of manufacturing the entire armor-plate, the iron portion thereof is made by the ordinary method of manufacturing wrought-iron armor-plates, and the bars forming the walls of the frame are made either of a similar quality of iron or of steel. The steel used for the plate C by preference contains about 0.8 of carbon and the same quantity of manganese. After the iron plate, with the frame and worked steel plate, has been heated in the furnace to say, 2000 degrees Fahrenheit, the same is drawn from the furnace and placed on its end, with the end b^1 having no frame on upwards, and a sufficient quantity of molten steel of suitable quality to resist shot, as before mentioned, is then poured into the space *c* between the iron plate A and the steel plate C. The combined iron and steel plate is then allowed to cool and solidify, after which it is re-heated in a furnace and reduced to the thickness required either by forging, pressing, or rolling, or by any of these processes.

If it is desired to run the molten steel into the space *c* from the bottom, the end portion *b* of the frame is dispensed with, the two sides *aa* only being used.

By manufacturing, in the manner prescribed, armor-plates of iron and steel in combination, the result is the production of a plate in which the steel is capable of presenting the greatest resistance to the penetration of shot, and the iron has the least liability to fracture or cracking, and the worked steel-face plate, while presenting an extraordinary resistance to the shot, enables the plate to be bent when hot to any required angle without showing any cracks; and, since the face of it is formed of steel previously worked, a better quality is

Fig. 1.

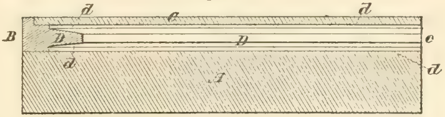


Fig. 2.

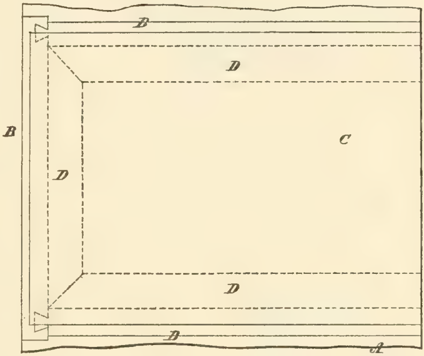
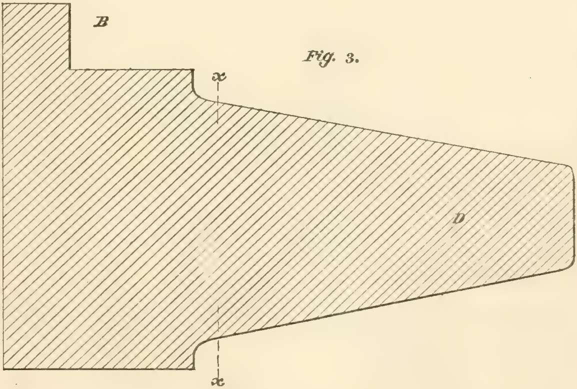


Fig. 3.



MANUFACTURE OF COMPOUND-ARMOR—ELLIS' PATENT.

ensured, and a sounder and more reliable plate is obtained than can be produced by existing methods.

In 1882, a further patent was granted:

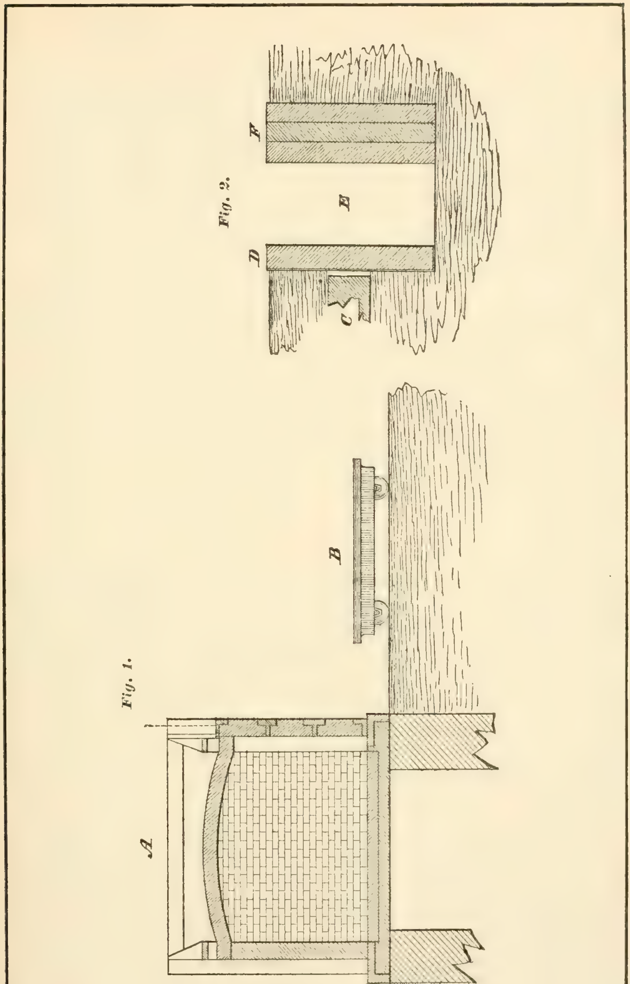
My said invention relates to the manufacture of armor-plates of iron and steel united or combined according to the improved method or means for which I obtained letters patent in 1880. My present invention has for its object to cause a part of the iron or steel frame (which is placed on the wrought-iron plate and which supports the outer steel plate) to be situated between and at the edge of the steel which is cast between the said plates, this part forming a part of the finished plate and giving thereto great soundness at the edges of the said cast steel. According to my said invention the frame is formed with a web or webs or a portion or portions which when the frame is in position projects or project into the space between the iron and steel plate into which space the steel is to be cast. The said web or webs or projecting portion or portions is or are preferably of a wedge shape in section, the lesser part being presented inwards. The molten steel cast between the two plates runs into the spaces between the said web or webs or projecting portion or portions and the plates on either side so that the outward part or edges of the finished plate is or are formed partly by this web or portion or webs or portions. The frame made according to my invention may be of wrought-iron or steel, but is preferably of worked steel, and may be used for the sides of the plate only, or for the sides and the end.

Figure 1 (Plate XVII.) is a transverse section of the wrought-iron plate A and worked steel plate C with the frame forming the space *c* between them for the reception of the molten steel.

Figure 2 is a plan of the same, and figure 3 is a transverse section of the frame drawn to a larger scale. Each member (that is, each side piece and the end piece) of the said frame has projecting from its inner side a wedge-shaped or tapering web D, projecting into the space which is to be occupied by the molten steel. Between the said web D, and each of the plates A and C, are spaces *dd*, into which the said molten steel will run. I do not limit myself to the form of web shown, as it may be of any convenient shape ; for example, one side only may be inclined or wedge-shaped and the other be at right angles to the plate, or both sides may be parallel with each other, or it may be thickened at the end or edge. Also there may be two or more webs of smaller size if desired in place of one large web as shown. The plates and frame are subjected to heat and the molten steel passed into the space between, and the combined plate afterwards treated and rolled after the manner described in the specification of my aforesaid patent. The plate may be cut as shown by the line *x* so that the projecting part or parts or web or webs D of the frame will form a part of the edges of the finished plate.

The method at present employed is to prepare the plates for compounding as in Plates XVI. and XVII.

They are then carried to the heating-furnace A (Plate XVIII.), figure 1, where, after covering all exposed steel surfaces with ganister, they are brought to the



MANUFACTURE OF COMPOUND-ARMOR—ELLIS' PATENT.

proper heat. The mass is then withdrawn from the furnace by huge pincers attached to a chain passed around the rolls, and landed upon the iron truck B, at the mouth of the furnace. The truck is run under the traveling crane, whose nippers are hooked to the plate. These nippers are very ingenious and constructed with an eccentric to shift, in lifting, the plate from a horizontal to a vertical position. The crane then carries the plate to and lowers it into the sunken iron pit, figure 2, where the hydraulic ram C pushes the movable iron plate D against the mass, lowered into the space E, and holds it in place, against the side F (composed of three iron plates), to receive the molten steel.

The space between the iron and steel plates is then filled with Bessemer or open-hearth steel, as desired, run from the ladle into a trough, lined with refractory material, and pierced with several holes to distribute the flow. The whole mass is then covered with sand and heavily weighted. After cooling, the plate is reheated, rolled to the desired thickness, bent, cut, planed, and tapped as required for the finished plate.

In rolling, water is thrown, at intervals, upon the mass to remove the impurities on the surface ; and whenever there is an appearance of a blister, or raised lump, it is removed by placing a sharp punch upon it, at the end of a large shaft, and striking into the blister to let the air out.

The largest plates weigh about 50 tons, and cost from £85 to £90 per ton.

Charles Cammell and Company.—The Cyclops Steel and Iron Works, in addition to its immense steel and iron products, is another great compound-armor manufactory. While the quality of the plate seems to be about the same as that manufactured under the Ellis patents, a different method of building up the armor is employed. The works cover some 53 acres, and are well supplied with tools and implements. The steam-hammer has a tup of 30 tons, a stroke of 7½ feet, with a steam pressure of 60 pounds.

The following are some of the principal patents under which the Cammell-Wilson compound-armor-plates are fabricated:

In 1877:

The object of this invention is so to treat armor-plates made of wrought or cast-steel in any well known or approved manner that the character of the metal to a given depth of the plate will be changed, the hardness and brittleness of the steel being replaced by toughness and malleability, whereby the plate will present a combination of resisting forces the best calculated to insure its impenetrability to shot and shell. Supposing, for example, it be desired to give the plate a soft or toughened back, and to retain the natural hardness of the steel at the face of the plate, the hard face serving to prevent penetration, and the soft back the starring or breaking away of the hard face, I proceed in the following manner : I take a plate of steel, say twenty inches thick and of any desired length and breadth, which may have been either *cast* or *wrought*, and

containing any desired proportion of carbon, and I proceed to decarbonize the plate to a depth of about eight inches more or less, leaving the remaining twelve inches unchanged. Having provided a cast-iron box, I cover the bottom of the same with a layer of charcoal, and on this charcoal I place the steel plate, which has previously been coated with black lead or graphite on its under side and up its edges to a height of twelve inches, or the depth at which I intend to retain the plate unchanged. I then fill the space between the edges of the plate and the inside of the box with ganister to the height of twelve inches, and to the upper part of the plate, both on its face and at its edges, I apply oxide of iron or other decarbonizing agent. I then place a cover on the box, and having luted it, I run the same into an annealing oven, suitably constructed to receive about four or more of such boxes. When the oven is charged and the entrance to the oven is built up with fire-bricks, I heat the oven by means of coal fires, and maintain the temperature for a sufficient length of time until the decarbonization of the upper eight inches is effected. The oven is then allowed to cool down gradually, and the boxes with their plates are withdrawn.

By this treatment it will be found that the protected portion of the plate, or that part which was covered by graphite, will retain its hardness, while the portion exposed to the oxide of iron will have acquired the toughness desired.

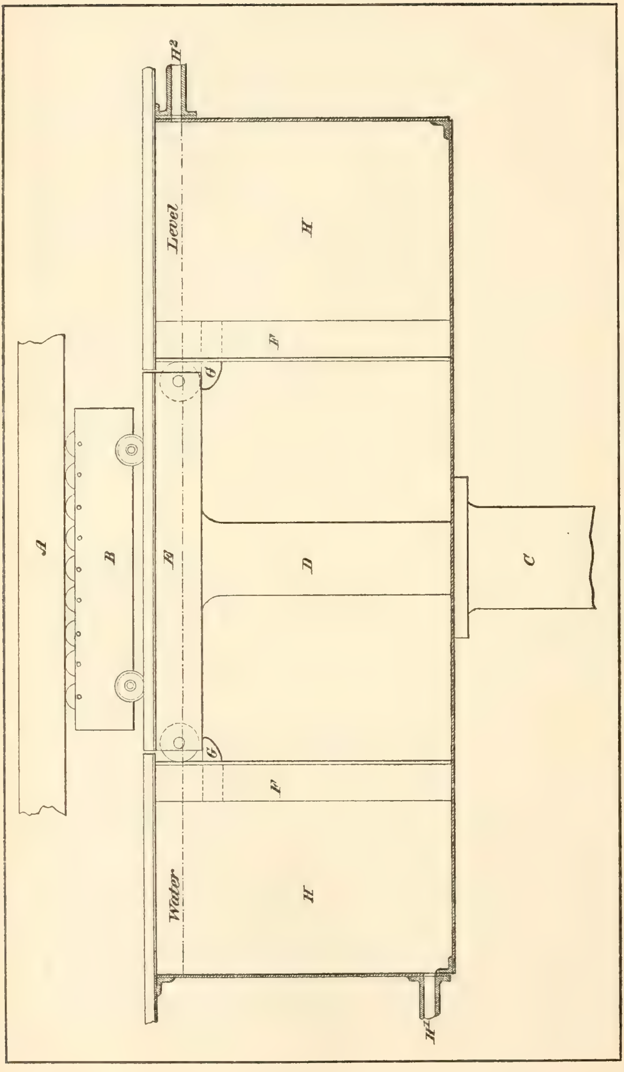
It will be readily understood that both faces of the plate can, if desired, be decarbonized, and that to any given depth, while the central portion of the plate retains its hard character.

Again in 1877 :

This invention has for its object improvements in the manufacture of armor-plates. For this purpose I take an ingot of steel of the nature of mild steel, that is, containing only a small proportion of carbon, and after hammering it or pressing it down under a hydraulic press, or rolling it to the required thickness, I re-heat the plate or not, and plunge it in its heated state into water or other fluid.

A (Plate XIX.) is a thick, massive armor-plate forged from an ingot of mild steel, as above described, and re-heated. After being re-heated, it is run on to a truck B, and conveyed by the truck on to the table E, which at this time is supported by the stop bolts G. At the ends of the table are rollers working against vertical guides F, at the sides of a tank H. D is a hydraulic ram descending from the center of the table E, and entering the hydraulic cylinder C. Water, or it might be other fluid, is now admitted constantly to the tank by the inlet H^1, and escapes by the outlet H^2. When the truck carrying the armor-plate has been brought on to the table E, the bolts G are withdrawn, and the table lowered by the hydraulic lift so as to immerse the armor-plate in the fluid, and the plate is left immersed in the fluid until cold.

In place of employing a hydraulic lift to lower the heated armor-plates into the tank, an overhead crane with chains, or other suitable raising and lowering apparatus, may be used for the purpose. By thus immersing in water or other fluid, thick, massive heated plates, which have been forged or shaped from ingots of mild steel, the metal is rendered extremely tough and tenacious, and the plates are far more capable of offering resistance to projectiles than plates allowed to cool slowly by exposure to the air, as has heretofore been done.



TEMPERING ARMOR-PLATES.—WILSON'S PATENT.

Again in 1877:

My present improvements have for their object the production of "hard-faced armor-plates" with greater facility and economy than by a former patent of 1876.

For this purpose I put edgewise, in any suitable furnace, two wrought-iron or soft steel "backing plates" any required distance from each other. I then place between such plates a "**T** core" made of ganister or other refractory material, the upper portion of which forms a covering to the space between the plates and the other portion, a division wall dividing the space between the plates into two spaces or moulds; I then pass heated gases through these spaces or moulds, until the exposed surfaces of the plates are heated to such a state as to insure a perfect union with the molten metal, which I afterwards run into the spaces or moulds, as already described in my previous specification above mentioned. When the molten metal has set, I withdraw the plates from the furnace, and, if required, I put them into a re-heating furnace previous to their being hammered or rolled down to any required thickness.

Figure 1 (Plate XX.) is a longitudinal section; figure 2 is a sectional plan; and figure 3 is a transverse section, showing my improved arrangements for the manufacture of armor plates in connection with a Siemens regenerative gas furnace.

The lines AA, BB, and CC mark the planes in which these sections are taken respectively. WW are two backing-plates set up face to face within the furnace, and T is the core which serves to divide the space between them into two separate cavities for the reception of molten steel.

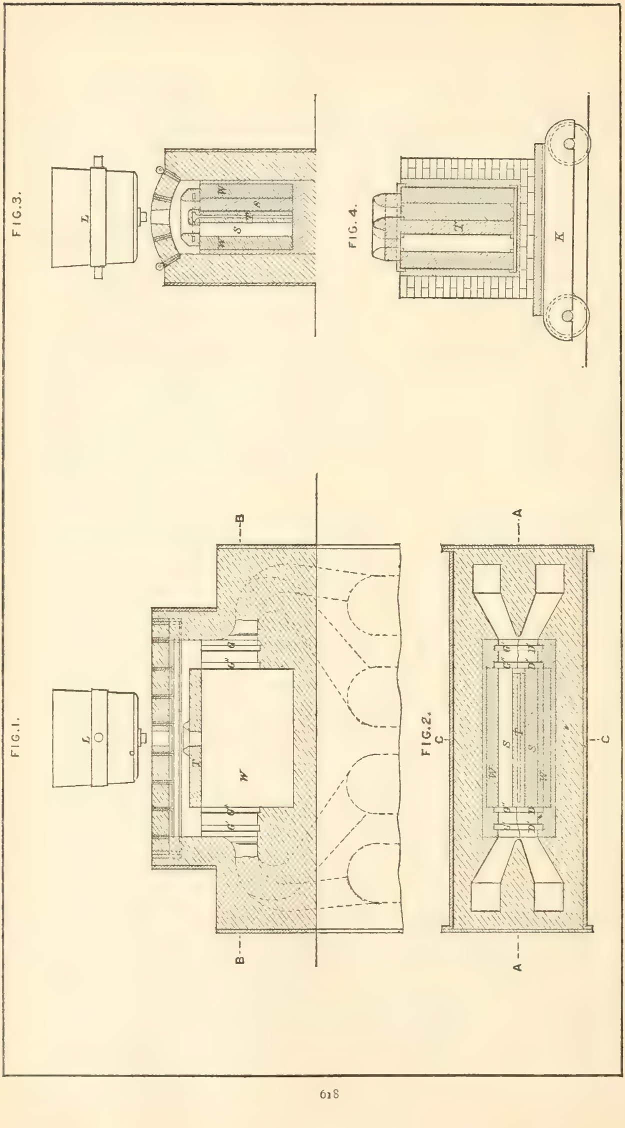
In figure 1, the lower part of this core is omitted, but the upper part which serves to close the mould at the top is indicated.

In figure 2, the upper part of the figure represents the position whilst the backing plates are being heated, the flame resulting from the combustion of the gas and air rising on one side of the furnace, traversing the spaces in the mould on either side of the core, and descending by the passages on the other side of the furnace to the regenerators. By this means the faces of the plates WW are thoroughly heated, and so also is the core T, between them. This having been done, the stopping slabs, D^{1}, D^{11}, are inserted into the grooves G^{1}, G^{11}, in the refractory lining of the furnace, as is represented in the lower part of the figure, and the space between them is filled with sand. All being ready, the steel is run into the cavities SS, from the ladle L, and so two compound-armor-plates are simultaneously produced.

The crown of the furnace is made in sections, so that it can be readily removed.

Figure 4 shows an arrangement differing from that already described, in that the body of the furnace is built upon a bogie or truck K. This bogie or truck may be taken away from the other parts of the furnace when the heating is complete to receive the molten steel, and may be replaced by another furnace body in which two backing plates are already set up ready for heating. Thus, much time in the working of the furnace is saved.

It will be readily seen that by this means I shall be able to manufacture plates



MANUFACTURE OF COMPOUND ARMOR—WILSON'S PATENT.

with greater facility and with a considerably less quantity of fuel, and consequently produce them cheaper than when they require to be re-heated, as described before in my other methods.

In 1878:

Heretofore, great difficulty has been experienced in producing reliable armor-plates entirely of steel, or of steel welded or run in a liquid state on to iron.

According to this invention I manufacture armor-plates by uniting a face of steel with an iron backing by soldering the two together by tin, zinc, spelter, bronze or such like.

The steel face of the plate may either be formed of a single thick plate of steel or preferably of a number of hexagonal, or it might be other shaped pieces, placed side by side and fitting one against the other; by this means any fracture which may be caused in any one or other of these portions of the steel facing will be localized, and will not extend to any of the other portions of the steel face.

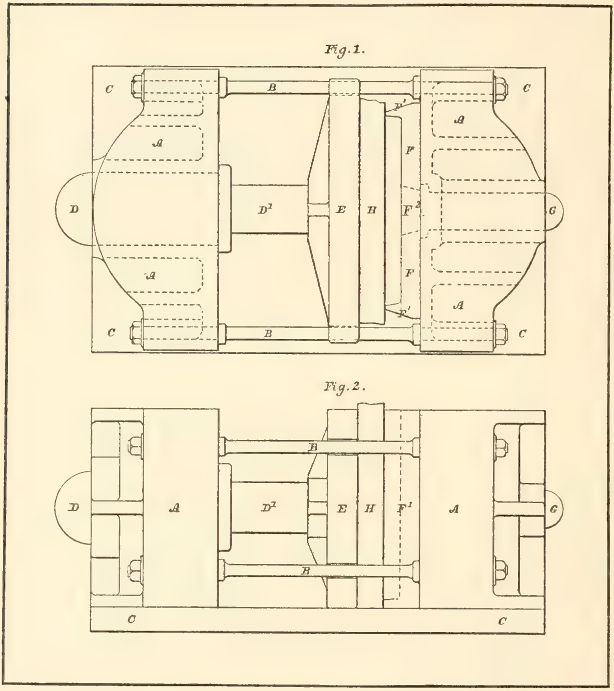
In 1882:

My present improvements have for their object to improve the means employed for carrying out a preceding process and are as follows, viz.:

As before, I take the wrought-iron backing-plate immediately it has been rolled down to the desired thickness; but instead of putting it into a complete mould I make the plate itself form one side.

Figure 1, page 620, is a plan, and figure 2 a side elevation showing two cast-iron bolsters A, connected together at a distance apart from one another by tie bolts B, both bolsters resting on and being secured to a bed-plate C. One bolster, A, carries a hydraulic cylinder D, the ram D^1 of which has secured in front of it a cast-iron plate E. The other has held in front of it the mould-plate F, from which, ribs, F^1, project forwards at its bottom and two sides. The bolster against which the mould-plate F is held also carries at its center a hydraulic cylinder G, the front end of the ram of which bears against a loose portion of the mould-plate F, marked F^2. H is the wrought-iron backing-plate which is to be faced with steel. As it comes from the rolling mill it is suspended from a crane by tongs and lowered in front of the mould-plate F—the plate E is then pressed forward against it by the ram D, and it is thereby held firmly against the edges of the ribs which project from the mould-plate. The figure shows the plate H as being thus forced against the ribs F^1, of the mould-plate F. When thus held, steel is poured into the cavity between it and the mould-plate. After the steel is set, both of the rams of the two hydraulic cylinders are simultaneously moved in a direction to carry the compound plate away from the mould-plate F; the plate can then be taken hold of by tongs in the ordinary manner and lifted away by a crane to convey it to a re-heating furnace, and when re-heated it is subsequently rolled down to the dimensions required.

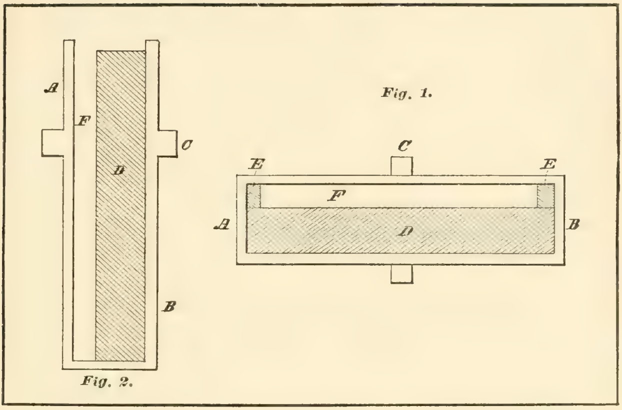
In place of the hydraulic cylinders D and G, strong screws might be used to effect the same objects, but I prefer to use hydraulic cylinders.



MANUFACTURE OF COMPOUND-ARMOR—WILSON'S PATENT.

The method now employed is to heat the wrought-iron plate (prepared in the usual manner by rolling several thin ones into one of the intended thickness) to the required temperature, when it is hauled out of the furnace, run upon rollers, and slid horizontally into the iron mould A B, figure 1, page 621 (lined with fire-proof material).

Iron strips E E are then inserted, and covered at the ends with moulding sand, to keep the plate D in place. The mould is then lifted by a crane to a vertical position, figure 2, and landed into a pit. The mouth of the mould is covered with a trough lined with refractory material and pierced with several holes to distribute the flow of open-hearth or Bessemer steel, as desired,



MANUFACTURE OF COMPOUND-ARMOR—WILSON'S PATENT.

which is run from a ladle brought from the furnaces by rail. The mould is then covered with sand and weighted.

After solidifying, the plate is finished in the usual manner.

Great confusion still exists in regard to the names of the compound armors. This has arisen from the fact that the managing directors, John Devonshire Ellis, of the firm of John Brown & Co., and George Wilson, of the firm of Charles Cammell & Co., are the patentees. Hence, the armor is sometimes named from the manufacturers, and as often called after the patentees.

The Brown plates are made under the Ellis patents, and the Cammell plates, under the Wilson patents.

Since the commencement of the manufacture of compound-armor, the superintendents of these two companies have received patents covering every detail from the character of the mould to the direction of rolling the plate, until, as will be seen from the above descriptions, at the present time neither firm employs the methods described in Very's "Development of Armor for Naval Use,"* nor do they restrict themselves to the use of steel manufactured by the particular processes there set forth.

I also take this opportunity to correct a statement made by Lieut. Very, in his valuable work, that, "In England the financial support

* Vol. IX., No. 3. Whole No. 25.

given by the Admiralty and the War Office to the firms of Cammell and Brown had enabled them to rapidly pass the first period of semi-failure and to turn out heavy compound plates as rapidly and with as great a certainty of regularity in resisting power as had been possible a few years before with iron plates."

At Mr. Wilson's request, I repeat his statement that, "instead of receiving 'financial support from the Admiralty and the War Office,' we had expended £30,000 in experimenting before a return of any kind was received from the Government."

The following report (I.) of the official tests at Spezia in September, 1883, for the reception of the Italia's armor-plates, ordered in Sheffield some time before, and the experiments (II.) at Shoeburyness in the same month, with the view of testing the amount of protection afforded to granite forts by armor-plates, will point out the present estimate of compound-armor in Italy and in England:

(I.) Spezia, September, 1883. On the 17th instant two steel-faced armor plates were tested at Spezia, which represented the armor for the Italia in course of completion at the two Sheffield works, and upon which the acceptance or the rejection by the Italian government depended.

After the experiments last autumn with steel and steel-faced plates with the 100-ton gun, it was decided by the Italian government that the conditions for the reception of the armor for the Italia should be as follows:

That the plates selected at each works, out of those made for this ship, should stand each one blow in the center from a Gregorini chilled cast-iron shell from the 100-ton, 45-cm. muzzle-loading gun at such a velocity as would completely pierce a solid wrought-iron armor-plate 25 per cent thicker; that the steel-faced plate thus tested should not be pierced, nor any portion of the plate fall from the backing. The plate to be under the same conditions of backing-frame, etc., as those tried last autumn, except that the number and disposition of the bolts were left to the manufacturers of the plates.

This test we believe had been proposed to the French makers of steel plates and declined by them. (See page 709.)

The plates tested on the 17th instant had been cut to about 8 feet x 8 feet, and measured respectively; Brown's, 45 cm. (cm. = .394 inch), Cammell's, 48 cm., thick. They were each held to the wood-backing by 16 bolts. Backing and frame were of the same dimensions as in the experiments last autumn. Distance of 100-ton M. L. gun from face of plate, 30 metres.

Cammell's plate was tested first; charge, 217 kilos. (kilo. equals 2.2 lbs.) of progressive Fossano powder, Gregorini chilled cast-iron shell, 912 kilos. Velocity at point of impact, 474 metres per second. Total energy, 10,440 dinamodes (dinamode = mêtre-tonne = 3.229 foot-tons), equal to 73.89 dinamodes per cm. of circumference of projectile. Plate struck fairly in center. Point of projectile stuck in face of plate; remainder broken up and scattered. Estimated penetration, about 220 mm. Plate cracked,

but no portion detached from target. Front of plate around impact dished to the extent of about 35 cm. diameter, and to a depth of about 75 mm. near center of the cracks. Three are supposed to be through cracks. This can be determined only by subsequent removal of plate from target.

For *Brown's* plate, being 45 cm. thick, the charge of powder was proportionately reduced to 196 kilos. Velocity at point of impact, 449 metres. Total energy, 9396 dinamodes, equal to 65.52 dinamodes per cm. of circumference of projectile. Estimated penetration, about 17.5 cm. Plate not struck in center, but 25 cm. too high and 15 cm. to the right ; consequently, upper right corner received an undue amount of the blow. Only three radiating cracks of any importance, two of which in right upper corner, probably through. Lower part of plate is almost intact and no portion detached from backing.

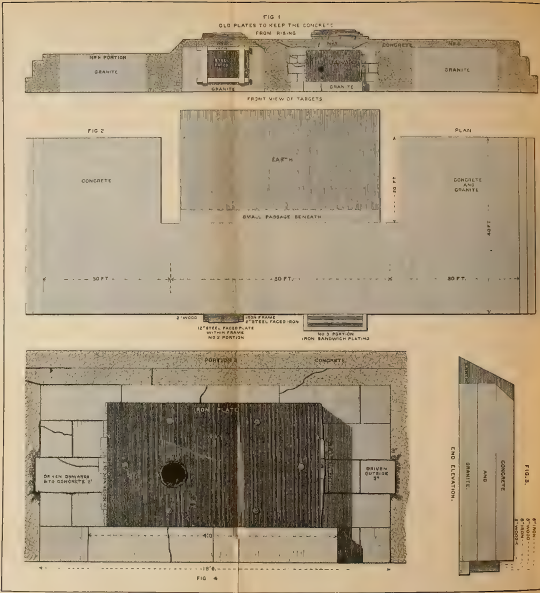
Both plates have thus satisfied the conditions of the contract, and the plates made for the Italia are consequently accepted.

The small amount of penetration as compared with the steel plates is again conspicuous, and the opinion of the makers as to the reason for the plates falling from the targets in November, namely, an insufficient number of bolts, is fully confirmed.

(II.) On Tuesday, August 22d, 1883, an experiment of great interest, especially to England, took place at Shoeburyness. It was carried out by the Royal Engineers with a view to testing the amount of protection afforded to granite forts by iron plates. The nature of the work tested is shown in Plate XXI.

Figure 1 shows the front, which is divided in four portions, the thickness of each being shown roughly in figures 2 and 3; that is, the plan and end elevation of the work. No. 1 consists of 40 feet thickness of granite and concrete ; Nos. 2 and 3, of 20 feet of granite and concrete, backed by about 20 feet of earth, but strengthened in front by iron shields, seen in figures 1, 2, and 3, hereafter to be described ; and No. 4 consists of 50 feet of granite and concrete. A small passage, of sufficient size to enable a man to creep through it, is pierced through the work parallel to the face and 20 feet from it, opposite portions 2 and 3, which would enable the effect of the fire to be better seen; so it was supposed, and so it proved. The shields fixed on the face of portions 2 and 3 were as follows : that on No. 3, against which the first shot was to be fired, consisted of two plates of 8 inches thickness each, of wrought-iron, sandwiched with 5 inches of wood behind each, made up of two thicknesses, that is, 2½-inch planks laid horizontally, next behind each plate, and 2½-inch planks behind them placed vertically. The dimensions of each plate were as follows : length 12 feet, height 7 feet, and thickness 8 inches. They were supplied by Messrs. Cammell. They were held in their place by six bolts, on the Palliser English system.

The shield on portion 2 consisted of 12 inches of Wilson's compound or other steel-faced iron, in a plate 7 feet by 7 feet, fixed inside an iron frame, as shown in figures 1 and 2. On the top of the work was laid a quantity of old broken plating, to keep the masonry and concrete from rising under the force of the blow. We can hardly think that structures of granite and concrete would at-



EXPERIMENTS ON PLATED FORTS AT SHOEBURYNESS

but no portion detached from target. Front of plate around impact dished to the extent of about 35 cm. diameter, and to a depth of about 75 mm. near center of the cracks. Three are supposed to be through cracks. This can be determined only by subsequent removal of plate from target.

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tain their full strength for many months, perhaps years to come, and must allow for this in this trial, which it will be seen is a very severe one.

The gun employed was the 80-ton gun, M. L., which was mounted at 200 yards distance. One round was fired from it on Tuesday at portion 3—iron sandwich on granite. A projectile weighing 1700 lbs. was fired with a charge of 450 lbs. of pebble powder, with a velocity of about 1588 feet. This implies a total amount of stored-up work of about 29,730 foot-tons, or 594.4 foot-tons per inch circumference, representing a power of perforating about 25 inches of iron. The shot was a service Palliser, chilled-iron projectile, of about 3 feet 8½ inches long, fired without bursting charge, the radius of the head being about 1½ inch diameter. The shot struck a point 3 feet from the bottom of the plate, and 3 feet 8 inches from the left end looking at it. The effects were as follows : The shot cut a clean hole, passing through both plates, and breaking up during penetration, turned rather to the left, the point reaching a depth of nearly 10 feet, measuring from the front face of the iron. The plates behaved admirably, the hole being cut almost without any apparent effect in the surrounding portion of the plate. The wood was driven outwards, 5 inches of the ends of the horizontal plates being thrust out beyond the plate at the left end, and 3 inches on the right. The granite was pulverized all round the projectile for some distance. Cracks were visible in the granite in front, as shown in figure 4. They will be observed to radiate from the point of impact, speaking generally. The stones of the course through which the shot passed were like the layers of wood, forced longitudinally, left and right, projecting 3 inches beyond the other at each end of the squares of masonry. One or two cracks also were visible in the brickwork lining of the small cross passage behind the part struck. The bolts do not appear to have suffered, and the general structure shows little effect beyond what is here mentioned.

The second round was fired on September 11th at Portion 2, the steel-faced plate, &c. The projectile was a Palliser shot weighing over 1700 lbs., the striking velocity being something under 1600 feet.

The effect is seen in figures 1, 2, and 3 (Plate XXII.), which show the plate, and figure 4, which shows the masonry behind it. It will be seen that the plate stood wonderfully well. The shot broke up, its head being fixed in the plate, figures 2 and 3. The plate was bent and bulged, the bulge and shot being pressed unusually flat against the masonry supporting the plate. There were great annular rents immediately round the shot, where much violent work must have been done ; the radial cracks were nearly all fine hair cracks ; the depth of the most important may be seen in figure 3. The bolts stood well, holding the plate up. They were subsequently broken to enable the back of the plate and masonry to be examined. Figure 4 shows the granite with the indentation and cracking made by the blow. This, it may be seen, is very slight. The deepest impression is that made by the shot point at A. The spring of the plate has opened the joints at the upper bolts B B, and if the side view, figure 3, be examined, it will be seen that a tremendous strain must have fallen on these bolts, though we do not understand that they gave way. Crack C was produced by the first round fired at Portion 3, figure 1, Plate XXI.

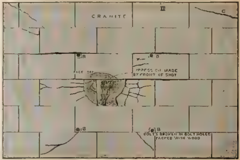
tain their full strength for many months, perhaps years to come, and must allow for this in this trial, which it will be seen is a very severe one.

The gun employed was the 80-ton gun, M. L., which was mounted at 200 yards distance. One round was fired from it on Tuesday at portion 3—iron sandwich on granite. A projectile weighing 1700 lbs. was fired with a charge of 450 lbs. of pebble powder, with a velocity of about 1588 feet. This implies a total amount of stored-up work of about 29,730 foot-tons, or 594.4 foot-tons per inch circumference, representing a power of perforating about 25 inches of iron. The shot was a service Palliser, chilled-iron projectile, of about 3 feet 8½ inches long, fired without bursting charge, the radius of the head being about 1½ inch diameter. The shot struck a point 3 feet from the bottom of the plate, and 3 feet 8 inches from the left end looking at it. The effects were as follows : The shot cut a clean hole, passing through both plates, and breaking up during penetration, turned rather to the left, the point reaching a depth of nearly 10 feet, measuring from the front face of the iron. The plates behaved admirably, the hole being cut almost without any apparent effect in the surrounding portion of the plate. The wood was driven outwards, 5 inches of the ends of the horizontal plates being thrust out beyond the plate at the left end, and 3 inches on the right. The granite was pulverized all round the projectile for some distance. Cracks were visible in the granite in front, as shown in figure 4. They will be observed to radiate from the point of impact, speaking generally. The stones of the course through which the shot passed were like the layers of wood, forced longitudinally, left and right, projecting 3 inches beyond the other at each end of the squares of masonry. One or two cracks also were visible in the brickwork lining of the small cross passage behind the part struck. The bolts do not appear to have suffered, and the general structure shows little effect beyond what is here mentioned.

The second round was fired on September 11th at Portion 2, the steel-faced plate, &c. The projectile was a Palliser shot weighing over 1700 lbs., the striking velocity being something under 1600 feet.

The effect is seen in figures 1, 2, and 3 (Plate XXII.), which show the plate, and figure 4, which shows the masonry behind it. It will be seen that the plate stood wonderfully well. The shot broke up, its head being fixed in the plate, figures 2 and 3. The plate was bent and bulged, the bulge and shot being pressed unusually flat against the masonry supporting the plate. There were great annular rents immediately round the shot, where much violent work must have been done ; the radial cracks were nearly all fine hair cracks ; the depth of the most important may be seen in figure 3. The bolts stood well, holding the plate up. They were subsequently broken to enable the back of the plate and masonry to be examined. Figure 4 shows the granite with the indentation and cracking made by the blow. This, it may be seen, is very slight. The deepest impression is that made by the shot point at A. The spring of the plate has opened the joints at the upper bolts B B, and if the side view, figure 3, be examined, it will be seen that a tremendous strain must have fallen on these bolts, though we do not understand that they gave way. Crack C was produced by the first round fired at Portion 3, figure 1, Plate XXI.

FIG 4



AFTER REMOVAL OF FRONT COMPOUND PLATE

FIG. 3

FIG. 1

STEEL FACE
CAMMELLS (WILSONS) COMPOUND PLATE
FRONT VIEW REMOVED FROM PORTION II

FIG. 2

IRON BACK
CAMMELLS (WILSONS) COMPOUND PLATE
BACK VIEW

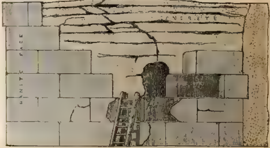
FIG 7

SHOT FROM WROUGHT IRON PLATE PORTION III

FIG 8

SHOT FROM GRANITE PORTION I

FIG 5 PORTION I.



AFTER ... GRANITE ... ABOVE POINT OF IMPACT, SHOWING GENERAL CONDITION OF CONCRETE

FIG 6. PORTION IV

SHOWING HOLE WHERE SHOT ENTERED ... IN PROCESS OF REMOVAL TO GET OUT SHOT

EXPERIMENTS ON PLATED FORTS AT SHOEBURYNESS.

Figure 7 (Plate XXII.) represents the shot of the first round, its fragments being assembled. The cracks in the masonry, as before, nearly all radiate from the point of impact.

Taking this round as nearly the same as No. 1, we may say that about 30,000 foot-tons work have been delivered on this shield, and that a compound 12-inch plate has, under the conditions before us, borne the blow of a shot capable of perforating about 25 inches of iron. The plate is an admirable one.

Round 3 was at Portion 1, the granite and concrete. The projectile, fired with approximately the same energy as in the previous rounds, entered the masonry about the spot marked A in figure 5, dislodging and breaking the stones in the immediate vicinity, and penetrated through the 5 feet of granite and 13 feet of concrete, keeping a fairly direct line until it came against the second granite layer; here its point, after destroying a little of the granite face, turned sharp off to the right, broke, and it soon came to rest, the shot having thus first gone directly to a depth of 18 feet, and then laterally about 7 feet. Figure 5 shows the upper granite stones removed. The concrete may be seen to be lifted, cracked, and in a "demoralized" condition generally. Figure 8 shows the shot fragments assembled. The fourth round, which nearly resembled those already fired as to its velocity, was discharged on September 20th. It entered Portion 4, concrete only. Figure 6 shows the present condition of the target. The shot has attained a depth of considerably over 24 feet, perhaps over 30 feet, but at the time we obtained our information it had not been found. It is not entirely through the 40 feet or even nearly so, or there would be more signs of its presence at the back.

We expected the shot and plate to suffer more, and the masonry to be less penetrated in the case of the steel-face plate, than in the case of the iron; but we confess we did not expect to see the plate stop the shot altogether, as it has done in this instance. How is this to be accounted for? The natural suggestions are inferiority in shot, special excellence in plate, or special support given to this nature of plate by hard backing. There does not appear to be any reason to call the shot bad. The plate is certainly excellent, but we think that the last-named cause told most—that is to say, that very hard backing specially brings out the powers of steel-faced plates. This supports the opinion of the Italian Committee, who considered that the yielding backing at Spezia told much more against the compound plates than the steel. Any one who looks at the indication of concentric hair cracks which are apt to be formed in compound plates, almost like the circles round a stone in water, will perhaps concur in thinking that the value of hard backing to this class of armor is peculiarly great.

Unquestionably, the shield is a wonderfully good combination, and very far better than the sandwiched iron one, which has not the hard steel face, and whose soft layers gave the shot the opportunity of getting its head in, and attacking the granite fairly well.

With regard to these two masonry targets, it is difficult to speak exactly; as we before remarked, we think that the concrete has not a fair chance, owing to its having been made so short a time. Apparently the granite bears something

the same sort of relation to the concrete as the steel-faced plate bears to the iron one: that is to say, it stops the shot more abruptly. The arrangement of alternate layers may be good for the shot in Portion 1, which, turned off from the second layer of granite, would probably have experienced more difficulty in doing so, had its base been surrounded by granite instead of concrete. As it was, as soon as its points had felt the second face of stone, the shot turned off at something beyond a right angle, moving harmlessly for a short distance and breaking up, as an officer expressed it, by its attitude almost protesting, "Not another layer of granite." If instead of shot, charged shell had been used, the effect on concrete might have been disastrous, but concrete might be faced with a comparatively thin steel plate which would explode the shell, and so save the backing.—*London Engineer.*

> "Until within a very few years, the steel for gun metal has been confined in England to that produced from crucibles, and it is only since the general application of the Siemens-Martin process that open-hearth steel has come into competition with it."*

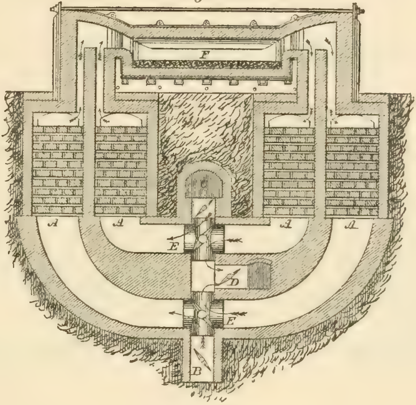
Of this process, Lieutenant Chase gives the following:

The Siemens furnace is one heated by the combustion of gas, effected in the furnace itself. All kinds of gaseous fuel may be burned. That which especially distinguishes the Siemens from an ordinary gas furnace, is, that there is stored in the spacious apparatus called *regenerators* the greater part of the heat possessed by the gases on coming out of the oven, and that all the heat so stored is utilized for raising the temperature of the furnace. The regenerators, generally four, are usually arranged below the sole of the hearth, and are chambers of refractory brick placed in horizontal layers, having intervals between them to present a larger surface of contact for the gases and air. Two of these regenerators communicate with the right, and the other two with the left end of the furnace.

The mixture of combustible gases and atmospheric air necessary, arrives in the furnace F, figure 1 (Plate XXIII.), after having traversed the two regenerators A of same couple. The combustion takes place in the furnace, and the products of this combustion reach the chimney D, after traversing the other two regenerators A. The bricks of the regenerators store up the greater part of the heat possessed by the gases on leaving the furnace. By the aid of valves, E, the gases and air are sent into the regenerators of the last couple, which are now heated, and the products of combustion go into the chimney by the other two regenerators. The gases and air, by rising slowly through the chambers of the right couple, are heated according to the temperature of the bricks, and reach the hearth at a temperature near to that of the furnace itself, so that their combustion develops a very intense heat, and the temperature of the furnace increases in consequence. The temperature is raised at each reversal of the valves E, effected at regular intervals (or, if the gas-producers do not work

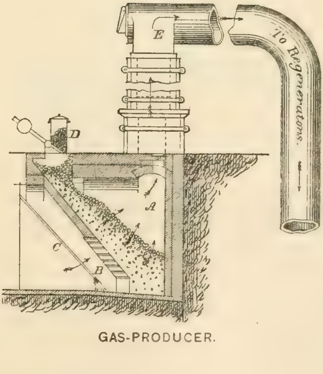
* Gun Foundry Board Report.

Fig. 1.



REGENERATOR.

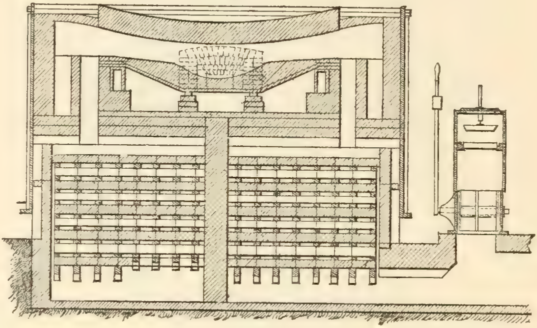
Fig. 2.



GAS-PRODUCER.

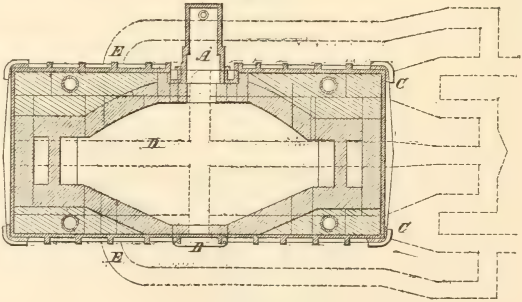
OPEN HEARTH FURNACE.

Fig. 3.



VERTICAL SECTION.

Fig. 4.



SECTIONAL PLAN.

OPEN HEARTH FURNACE.

regularly, at periods indicated by the working of the oven). The volume of the gases is regulated by a register, C. As for the air, its volume is regulated either by the damper B or the chimney-damper D, modifying the draft of the furnace.

The gas-producer, figure 2, transforms the fuel into gas. This apparatus usually consists of a chamber A of refractory brick. Three of the walls are vertical, and composed of two layers of brick, between which is a bed of sand to prevent loss of heat. The fourth wall consists of an inclined plane, that which fuel will naturally take, the upper part of which is formed of iron plates covered with refractory brick, while the lower part is an open grate B, with flat horizontal steps. The bottom of the producer is a little inclined to form a basin to hold water, brought in by the pipe C. The roof has two orifices, D, furnished with hoppers and valves, regulating the feed of fuel. A square chamber permits the gas to pass into the pipe E, which conducts it to the furnace.

The furnace for the Martin-Siemens process (figures 3, 4, Plate XXIV.) is a reverberatory, with a single door A in the middle of one of the long walls; facing it on the opposite side and at the lowest point of the sole, is the tapping-hole B. The gases from the Siemens apparatus, and the atmospheric air to burn them, arrive and escape by the two ends CC, EE. The interior section of the furnace, D, is a rectangle narrowed at both ends. The sole is of refractory sand. In order that it may resist the high temperature of the furnace, it is given little thickness. A strong plate of iron, cooled from below by a current of air, supports the sand.

The furnace, heated to a white heat by the hot gas from the regenerators, receives a certain quantity of cast-iron, charged hot, to be refined. When this is liquefied and the bath very hot, the soft iron is added, previously heated to a bright red. These additions are made every half-hour, and are followed by a brisk stirring. When the tests indicate that the metal is sufficiently refined, cast-iron, heated red, is added. After the fusion of the metal which has been added, and a suitable stirring, tests regulate the proportion of cast-iron to be added. Additions are made and tests performed, until the product has reached the degree of carbonization wanted. Then the tapping is proceeded with. The duration of the operation is usually seven to eight hours.

" The uniform results that are now attainable with this process show that the period for the exclusive use of crucible steel for cannon has passed. Some of the steel manufacturers have advanced very far in the use of the open hearth, and all are making arrangements for embarking in this system of manufacture. This process is much cheaper than that by the crucible, and, its success being established, that reason alone would be sufficient to cause the change in the system ; but there are other reasons now operating in England which make the change of manufacture necessary in order that her steel works shall retain their position in commerce and be enabled to answer the calls made on them by the Government.

As long as the demand for steel was confined to orders which required small ingots, the product of the crucibles was sufficient, and the force of laborers required was not excessive; but since the introduction of steel into the process of forming armor-plates, and the corresponding increase in the size of parts requisite for the guns to pierce the new armor, the organization of a force to cast, from crucibles, masses to answer these demands has become a difficult matter. The changes that were commenced a few years ago in some, and which are now being introduced in all the works at Sheffield, are necessary to prevent the purchase from other sources of the masses of steel now required by the Government.

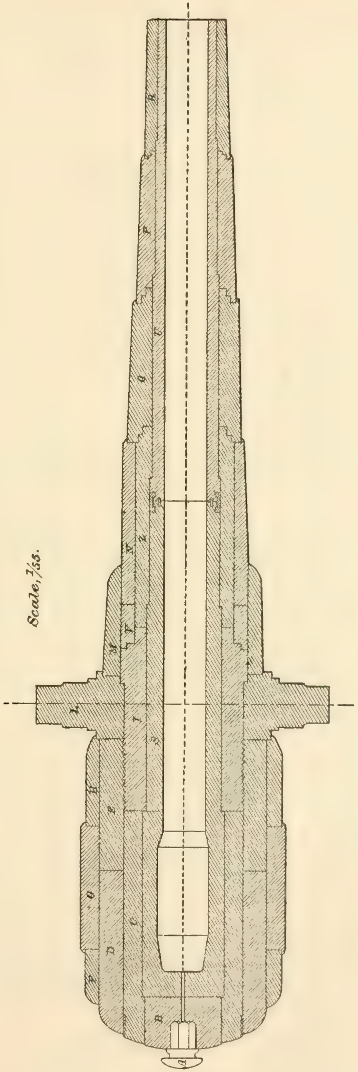
The new departure in the system of gun construction, described farther on in this report, will demand from the Sheffield steel manufacturers increased effort. Up to the present time the only portion in the construction of the Woolwich gun that required steel was the tube; the breech-pieces and hoops, being made of coiled wrought-iron, were fabricated at Woolwich. The new construction requires that steel shall be used throughout, and the castings for the jackets for guns now in hand at Woolwich can hardly be supplied from Sheffield. It is well known that the tubes for the 100-ton guns (Plate XXV.), manufactured at Elswick, by Sir William Armstrong, which required an ingot of 42 tons, had to be made in two pieces because the capacity of Sheffield was not sufficient to make the casting in one."*

WEIGHT OF PARTS. (PLATE XXV.)

A.........	0.049	tons.	H.........	3.678	tons.	R.........	1.536	tons.
B.........	1.046	"	I..........	7.764	"	S.........	8.827	"
C.........	9.512	"	L.........	7.924	"	U.........	5.029	"
D.........	8.319	"	M.........	5.225	"	V.........	1.242	"
E.........	8.761	"	N.........	4.135	"	Z.........	4.184	"
F.........	3.334	"	O.........	4.773	"			
G.........	13.205	"	P.........	3.285	"	Total,	101.828	"

As shown in the Plate, the steel tube is provided with a large number of shoulders, the hoops are narrow, and more numerous than in smaller calibers, and the breech is strengthened with three layers of hoops. While sufficient tangential strength was undoubtedly provided, the rupture of the Duilio's gun plainly indicated that the construc-

* Gun Foundry Board Report.



Scale, 1/35.

17·75-INCH 100-TON ARMSTRONG M. L. R.

tion was weak, and that the longitudinal strength was wholly inadequate. This was partly met in the new constructions by fabricating the tube in one piece.

> "It is fair to suppose that the use of the *coiled-steel* breech-pieces, now used at Woolwich to build up the 43-ton gun, was induced by the difficulty of procuring masses of steel of sufficient magnitude to make proper jackets for them. If this be not the case in regard to the 43-ton guns, the embarrassment is very likely to arise with the 62-ton steel gun now in contemplation. But whether any serious embarrassment has yet arisen or not, owing to the limited capacity of Sheffield for casting gun-metal, it is evident that whatever margin the manufacturers now have, it is very slight, and it behooves them to increase their plant for casting.
>
> The question of *forging* steel ingots is one which is evidently occupying the attention of the steel manufacturers in Sheffield, but on which they are reticent. The important works are all supplied with steam-hammers of greater or less weight varying from 15 to 25 tons, and each manufacturer claims that his works are thoroughly equipped in this respect for accomplishing the necessary work on an ingot of any size; but it was observed that in one important establishment preparations were being made for the introduction of a large press to take the place of, or to supplement the work of, the hammer. The success of Sir Joseph Whitworth's process of forging by hydraulic compression, and the enviable character acquired by the products of his works in Manchester, have induced the Sheffield manufacturers to take into consideration the probable advantages of the process. As to the advantage or practicability of the compression of steel in the liquid state they are entirely skeptical, but the efficacy of forging under hydraulic compression is conceded, though it is claimed that this must be done under a heat much higher than that required for forging under a hammer, which is considered an objection to the process." *

Experiments on a very small scale have been made with liquid-compressed steel in the United States, at Pittsburgh, Pa., and Newburgh, N. Y., but the production has been so limited that it can be looked upon only as an experiment.

* Gun Foundry Board Report.

"Owing to the character of seclusion that Sir Joseph Whitworth has preserved to his works, the manufacturers of steel at Sheffield have no personal knowledge of the process adopted at Manchester. Their knowledge is limited to meagre reports, but the Board was allowed the privilege of carrying on its investigations within the works, where, under orders from Sir Joseph, his representatives exhibited, with explanations, the operations carried on in this unique establishment. It may be distinctly asserted that the experiences enjoyed by the Board during its visit amounted to a revelation.

Whitworth's Works.—Upon its first arrival in London, the Board was invited by Sir Joseph Whitworth to examine his works, but with the desire expressed that the visit should be postponed until the close of our foreign investigations. This request was, of course, readily acceded to, and it will be thus seen that previous to the visit to Manchester the members of the Board had received all the impressions that could be produced by viewing the operations at the chief steel factories in France and Russia, and the great factories of Sheffield, in England." *

These works of Sir Joseph Whitworth & Co., Manchester, are under one immense roof, and contain, without exception, the finest plant in the world for the manufacture of gun steel. This superb establishment is the result of many years of careful study, built up at an immense expenditure, and may well be imitated as a perfect type. The excellent arrangement of its tools and appliances, and the economic management are displayed in the very high character of the products. The distinguishing characteristics of the Whitworth fluid-compressed steel are homogeneity, strength, and ductility. It is made of various tempers to suit all purposes, particularly where it is exposed to sudden and violent strains. It is the most suitable for torpedo-cases, and is used by Mr. Hotchkiss and the French Government for all revolving cannon and rapid-firing guns. No other metal possesses the same endurance. In the consideration of the proper metal to be recommended for the army 12-inch rifles in 1882, the Ordnance Board concurred "with Captain Smith in recommending that the tube for the first should be of Whitworth's fluid-compressed steel, and this should be taken as the standard for our manufacturers to work up to in future constructions of this character."

* Gun Foundry Board Report.

In regard to his ordnance, Sir Joseph Whitworth for more than a quarter of a century has held that "*steel and steel alone* should be used in the construction of guns," and in regard to gun construction generally he has thus expressed his views :

It may be mentioned that when rifled guns were first adopted in the service they were breech-loaders : but their construction, and the comparatively weak wrought-iron of which they were made, only allowed in the 7-inch bore gun, 4 tons weight, a charge of 14 pounds of powder, and the shot was two diameters long, weighing 110 pounds. Such being the state of things at that time, I made a 7-inch bore muzzle-loading gun, 7 tons weight, charge of powder, 22 pounds, and a shot three diameters long, weighing 150 pounds.

This gun was consequently far more powerful than the service breech-loading gun of the same bore, and the War Department had other muzzle-loading guns made of the same proportions as regards weight and bore.

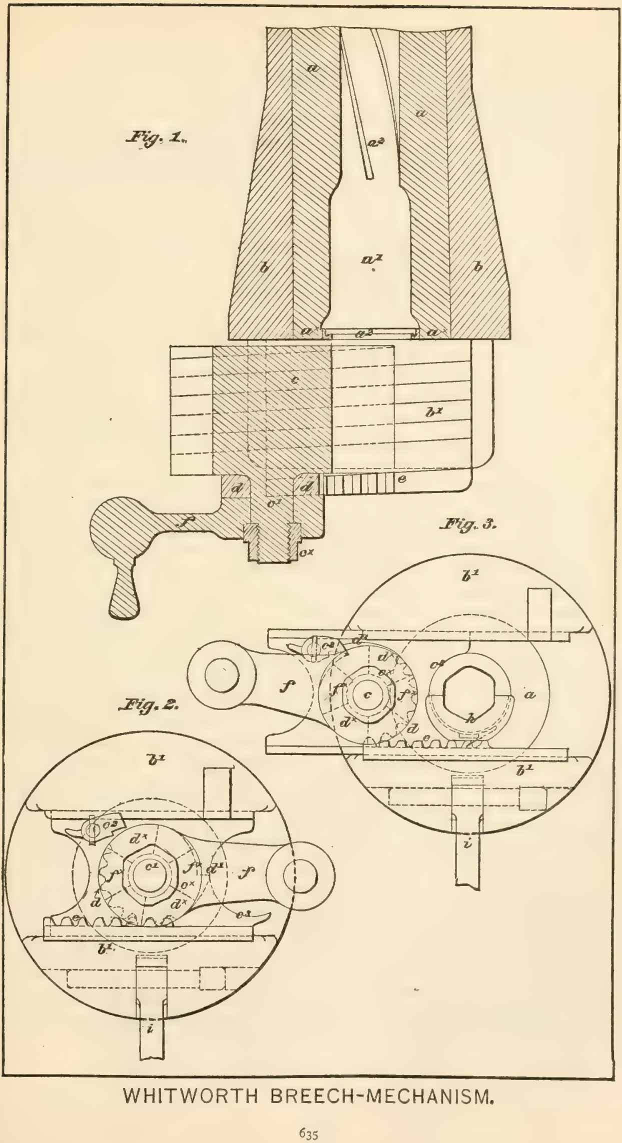
When fluid-compressed steel proved so completely master of gunpowder, the writer at once saw that more powder might be fired from a breech-loader with a large powder-chamber than could be consumed in a muzzle-loading gun.

Guns of enormous size are now being made at Woolwich at an enormous expenditure. These guns must needs be powerful on account of their great weight and size ; but the writer maintains that this enormous size is unnecessary. But if monster guns were wanted, they could be made at far less cost by means of the Siemens-Martin process and fluid compression. Supposing a hoop was wanted, say, 20 tons weight, the time required for its production by this process would not, commencing with the raw material, he believes, be more than one-tenth the time required by the forging, coiling, and welding processes. Again, as regards quality of material, good iron was given up being used at Woolwich some time ago, as it was found that weak, poor iron was easier to weld and work than good iron.

It is just the contrary with the Siemens-Martin or the Bessemer processes, everything being in favor of using good material ; and the writer, wishing to convince the Admiralty and War Department of the superiority of his steel guns, particularly of the breech-loader, offered to lend them a 7-inch breech-loading gun, firing 33 pounds of powder, and also a 35-ton muzzle-loading gun, which fires an armor-piercing projectile five diameters long, 1250 pounds weight with a bursting charge of 58 pounds. Both these offers were declined, much to the surprise of the Brazilian authorities, from whom permission had been obtained to lend these two guns.

The day of trial may be postponed by the making of enormous guns which astonish and mislead the public, but it would be far better for an immediate trial to be made with the best guns of moderate size that can be produced. With strong, ductile, sound steel, the breech-loading gun, with its large powder-chamber, whatever be the size, must be superior to the muzzle-loader.

To prevent being misunderstood with reference to the weight of guns in relation to their bore, it may be stated that the writer has, for ship guns particularly, advocated greater weight for a given size of bore.



WHITWORTH BREECH-MECHANISM.

The first 12-inch-bore guns made at Woolwich were 23 tons weight, afterwards increased to 25 tons.

In 1869 the writer submitted to the Admiralty a design for a 12-inch bore gun of fluid-compressed steel, and he specified that the weight of the gun must be 35 tons, for he had always considered that (except for a mountain gun) there should be 105 pounds weight of gun for every pound of shot of 3 diameters long.

It was, however, determined by a committee at the War Office that the gun should be made at Woolwich ; and the writer's weight for the size of bore was taken, and has been adopted ever since.

With weak materials, weak powder, long guns, and short projectiles must be used.

Strong, ductile, sound material allows of strong, quick-burning powder, short guns, long projectiles, and rapid rotation.

In regard to the general features of my plan of construction, the breech-closing arrangement of the gun consists of a breech-block sliding horizontally in grooves inclined at an angle to the rear face of the gun, the block being moved by means of a tappet handle which revolves a pinion-gearing into a rack on the gun ; the block is held in its place, when closed, by a catch.

Figure 1 (Plate XXVI.) is a horizontal section of gun ; figure 2 is a view of the breech end with the breech closed, and figure 3 is a similar view with the breech open ; *aa* is the tube ; *b* the breech-hoop or jacket ; b^1b^1 are the guides for the breech-block ; *c* is the breech-block with a straight line screw interlocking with the corresponding internal straight line screw on the block guides b^1. The sides of the threads are inclined inwards, so that the recoil of the breech-block has no tendency to separate the guides ; c^1 is a stud projecting from the back of the block, and *d*, a pinion upon it, gearing with the rack *e* on the block guide b^1 ; *f* is a weighted lever-handle on the same stud, and held thereon by the nut c^x. The interlocking projections on the pinion *d*, and lever handle *f*, are marked d^x and f^x ; c^2 is a pawl on the breech-block, which, by taking into a notch d^1 in the pinion, prevents it from running off the rack *e* except when the pawl is intentionally lifted ; a^2 is the gas-check ; c^3 is the cartridge guide formed on the breech-block ; *h* is the shot guide ; *i* is part of the link by which the gun is elevated.

The rifling is polygonal, being a hexagon with rounded corners. The powder-chamber is enlarged in diameter in order to burn an increased charge. There is also a slightly enlarged shot-chamber, to insure ease in loading.

All escape of gas is prevented by an elastic steel ring in the rear of the gun, and a disk in the face of the breech-block, which are pressed tightly together when the block is closed. This ring and disk are movable and can be readily replaced.

Owing to the simple form of the rifling, the projectiles for all the Whitworth guns are moulded by self-acting machinery, and fired as they are cast without being planed. By this means there is a saving in first cost, and, as there is no soft metal required to give rotation, the projectiles, when recovered after practice, can be fired several times.

The Whitworth system of breech-loading has been very severely tested with most satisfactory results.

The ease with which the breech-arrangement worked throughout the experiments was very remarkable.

The Brazilian Government have adopted the Whitworth ordnance, in consequence of the satisfactory results they had with it during the Paraguayan war. Many of the guns fired from 4000 to 5000 rounds without being damaged.

> " In speaking of the Whitworth establishment at Manchester as unique, and of the process of manufacture at that place as a revelation, reference is specially made to the operation of *forging*. As to the assorting of ores, and the treatment of metal in the furnaces, there is no intention to draw distinctions; but as to the treatment of the metal after casting there can be no doubt of the superiority of the system adopted by Sir Joseph Whitworth over that of all other manufacturers in the world. The process here adopted has been kept singularly exempt from scrutiny. Even in the offices of the chiefs of artillery there can be found no information, within the knowledge of the Board, which is at all satisfactory upon the subject. Whatever knowledge there is seems to come from hearsay—none from personal observation—and it is only from personal observation that the merits of the system can be fully appreciated."*

As early as 1863, Sir Joseph, then Mr., Whitworth was granted patents for the peculiar treatment of steel, and in 1865 he secured the right to " submit the liquid metal, as quickly as possible after it is poured into the mould, to a heavy pressure, even to the extent of tons on the square inch, by means of an hydraulic or other press; and in order to apply such heavy pressure, to construct the moulds of steel, in parts fixed the one to the other by screw-bolts and nuts, so as to be able to resist the great pressure applied to the fluid steel."

From that time until the present he has made improvements until his casting and forging plants are models of perfection.

> " The system of forging consists in compressing the liquid metal in the mould immediately after casting, and in substituting a hydraulic press for the hammer in the subsequent forging of the metal.
>
> The flask is made of steel and is built up of sections united by broad flanges bolted together in such numbers as to ac-

* Gun Foundry Board Report.

commodate the length of the ingot to be cast. All moulds are cylindrical in form. The interior of the flask is lined with square rods of wrought-iron, longitudinally arranged, which form, when in place, a complete cylindrical interior surface. Where the square edges of these rods meet, they are cut away, both on the inside and on the outside, and at intervals of two inches, small holes are drilled through between the rods, forming a channel-way from the interior to the exterior for the passage of gas and flame. The interior is then lined with moulding composition. The flange at the bottom of the flask, as well as that at the top, is perforated with small holes, which act as a continuation to the perforations between the segments of the lining for the escape of gas."*

Figure 1 (Plate XXVII.) is a front elevation, figure 2, a side elevation, of the press.

D are four hollow pillars secured to the base C, of the press, by the nuts x. The pillars have screw threads d^1 cut upon them along a portion of their length. On the top of the pillars is fixed the cast-iron head B, which carries the lifting cylinders E, in which works the ram F, and to its upper end is fitted the cross-head G, to which are attached two suspension rods H, coupled at their extremities with the massive movable head A. The moving head can be secured rapidly in any position by the nuts K.

P are spur-wheels for the locking-mechanism, into which the rack R gears. The handles Q are connected with this mechanism for locking and unlocking the head A. To the under side of the movable head A is bolted the plunger t, which enters the top of the mould, and is brought into contact with the surface of the fluid metal before the head is locked, and the pressure is applied by the large ram L within the cylinder R^1.

The base of the press consists of a massive foundation C, upon which is placed the large cylinder R^1 and ram L, for giving the pressure required, while above the cylinder is the table J, placed upon wheels. When the ram is lowered, and the pressure off, the table J can be run forward for the reception of the mould. When filled with fluid metal, the mould is drawn backwards by a horizontal hydraulic cylinder and ram, into its position beneath the movable head A.

The apparatus U is employed to record the movement of the pressing ram, and indicates the reduction in length while the casting undergoes pressure. The slide U, attached to one of the pillars, carries a lug, which is kept in contact with a projecting stop W fixed upon the table J, so that as the table rises with the ram L, the slide U is also carried up, and the amount of its movement is registered upon the dial V by the pointer Y. The split stops b, secured to the pillars by bolts and clips, are to support the head A when the press is not in use, thus relieving the lifting cylinders E.

* Gun Foundry Board Report.

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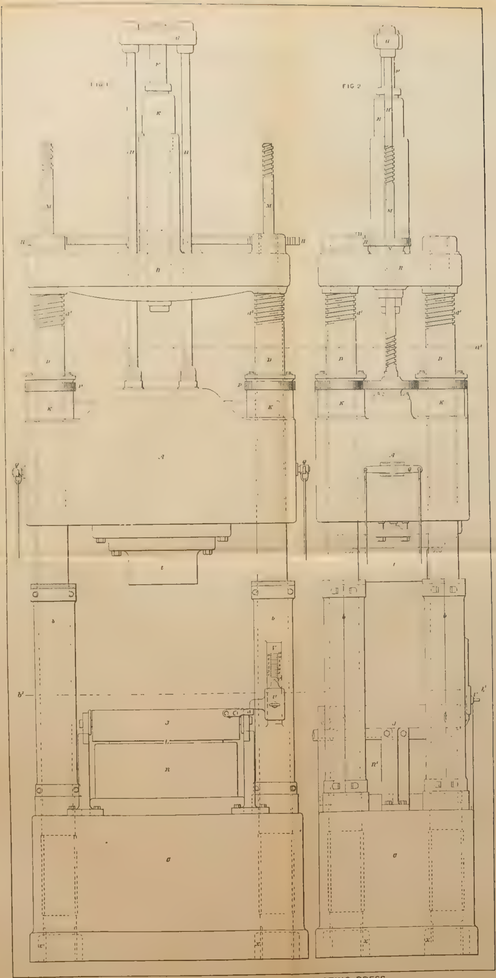
* Gun Foundry Board Report.



SIR JOSEPH WHITWORTH'S HYDRAULIC CASTING PRESS.

"The casting is made directly into the mould from the top. On the completion of the casting, the mould is moved (by means of a railway at the bottom of the casting-pit, which is a deep trench running parallel to the position of the furnaces) to a position under the movable head of the press, which is allowed to descend until the tup is in contact with the metal in the mould, and in this position it is locked; a shower of metal is induced, which ceases almost as soon as commenced, by the complete closing of the mould. The first impress felt by the metal is due to the weight of the head of the press alone. This pressure is gradually increased from below by hydraulic action, applied by four rams upon the table on which the flask rests, until the pressure exerted amounts to 6 tons per square inch. The interval from the commencement of the pressure until the maximum is reached varies with the size of the ingot, being for a 45-ton ingot as much as 35 minutes. During this time the flow of gas and flame from the apertures in the flanges of the flask, at top and at bottom, is continuous and violent, exhibiting the practical effect of the compression. This pressure is applied by the direct action of steam and pumping engines, and is indicated by a dial. At the end of this time the pump is taken off, and a uniform pressure of about 1500 pounds per square inch is established by attaching an accumulator to the press, and allowed to remain until the metal is sufficiently cooled to insure no farther contraction in the mould.

The contraction in length in the mould during the action of the pump, while the maximum pressure is being reached and sustained, amounts to one-eighth of the length of the ingot. After this effect has been produced, there is no farther advantage derived from the pressure in the way of eliminating impurities, but the contraction, in cooling, still goes on, and the pressure by the accumulator is considered necessary in order to follow up the metal as it contracts, for the purpose of preventing cracks being inaugurated at the end and on the exterior of the ingot by the adhesion of particles of the metal to the sides of the mould.

When cooled and re-heated, the ingot is brought under the influence of the forging press. This press is hydraulic, with a moving head having the main hydraulic cylinder fixed in it,

and it is provided with an arrangement of mechanism for raising and lowering the moving head of the press and for locking the same in any desired position. The press has four hollow pillars screwed part of their length, which are attached to the base of the press by nuts. On the top of the pillars is fixed a cast-iron head or table supporting two hydraulic lifting-cylinders, the rams of which are fitted with cross-heads carrying four suspension bars. These bars pass through the moving head, and are connected at the lower ends by cross-bars, which are fastened to the pressing ram. The moving head works between the base and the top or fixed head of the press, and is raised or lowered by the admission or exit of water from the under side of the rams of the lifting cylinders. The moving head can be firmly and rapidly locked at any height from the base which may suit the work to be operated upon. The moving head, as already mentioned, carries a forging or compressing cylinder, which forces a ram down upon the work. By attaching the compressing cylinder to, and making it part of, the moving head, a short stroke can be employed when forging objects which may vary in size from a few inches to several feet in diameter.

This in general terms explains the working of the ram. The effect produced by it requires to be seen in order to be thoroughly appreciated, and is altogether different from that produced by the hammer. The heated ingot resists the blow of the hammer, but the insinuating, persevering effort of the press cannot be denied. The longer time (several seconds) during which the effort lasts is a great element in its successful effect. As pressure succeeds pressure, the stability of the particles is thoroughly disturbed and a veritable *flow* of metal induced, which arranges itself in such shape as the pressure indicates; the particles are forced into closer contact and the whole mass writhes under the constraint which it is impotent to resist."*

Figure 1 (Plate XXVIII.) is a front elevation with the dial plate *f* and index *g* for indicating the movement of the ram at each stroke. Figure 2 is a side elevation. Figure 1 (Plate XXIX.) is a partial front elevation with swage block D′ and mandrel *h*″. Figure 2 is an end elevation, with a section of the hydraulic

* Gun Foundry Board Report.

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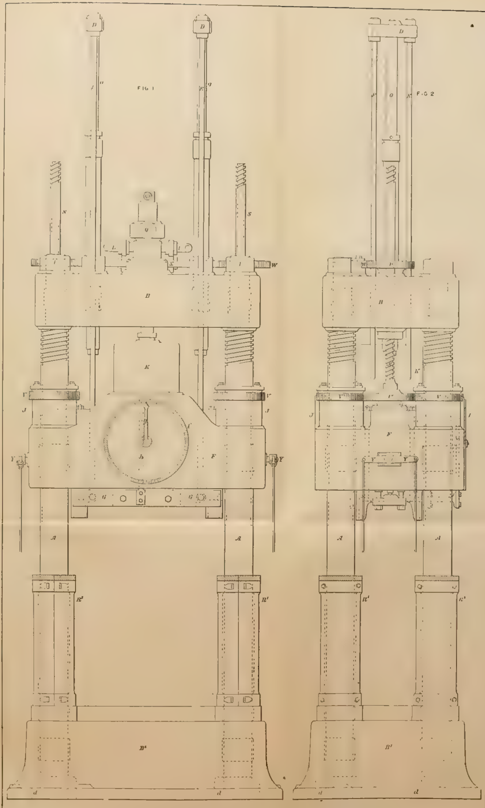
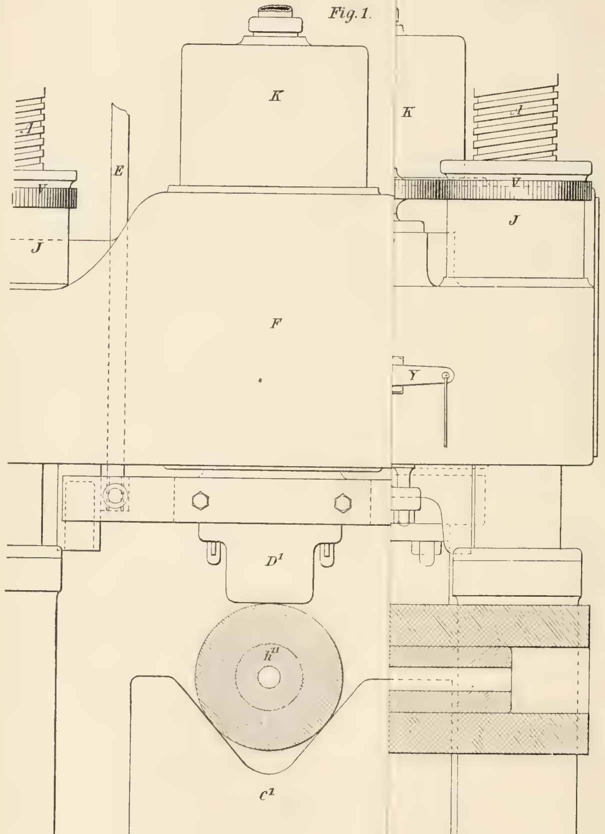
* Gun Foundry Board Report.

PLATE XXVIII



SIR JOSEPH WHITWORTH'S HYDRAULIC FORGING PRESS.

Fig. 1.



apparatus for withdrawing the mandrels from the forging. Figure 3 is a transverse section of this apparatus.

AAAA (Plate XXVIII.) are the four hollow pillars, screwed part of their length and secured to the foundation B^1 by the nuts *d*. B is the cast-iron head that supports the lifting-cylinders. The rams O are fitted with cross-heads D, from which are suspended the lifting-bars E. These bars pass through the moving head F, and are connected at their lower extremities to cross-bars G, which are fastened to the forging-ram. By these arrangements, the head F and forging apparatus can be lowered and rapidly secured in any position as the dimensions of the work decrease, and great economy is thus admitted in the expenditure of water, time, and power.

The moving head F is locked by means of the locking-nuts J, the quick-pitch screws S, passing through the nuts T, and the spur-wheels U. The nuts T are rotated by the rack W, actuated by the hydraulic cylinder X. The pitch-screws S are locked by a small movement of the levers Y, which actuate screws whereby the collars *w* are firmly gripped.

The moving head carries a forging-cylinder K, in which the ram works. The lifting-cylinders, when the press is at work, are kept in constant communication with an accumulator or other source of constant pressure, so that when the pressure is taken off the upper surface of the ram, the pressure acting upon the under side, rapidly raises the forging-ram.

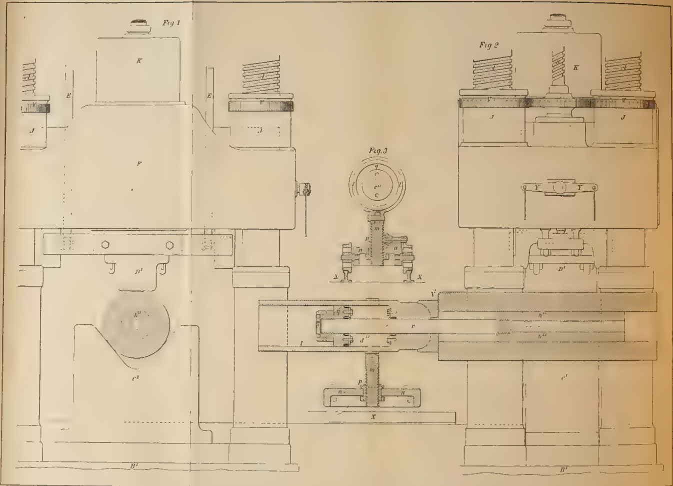
To indicate the amount of compression effected at each stroke, the dial-plate *f* is fixed on the face of the movable head F. The pointer *g* is attached to a pinion which is actuated by the rack *h* attached to the cross-bar G.

Split stops, secured around the pillars A by bolts and nuts, are for supporting the movable head F when the press is not in use, to relieve the lifting-cylinders of their load. They are made in halves for convenience in taking off.

To rotate the work under operation uniformly and through an equal space at each stroke of the forging-ram, an hydraulic cylinder is fixed vertically to the head B. Its ram is connected by links with a lever. The latter carries a pawl which works in a ratchet-wheel attached to the mandrel h'' (Plate XXIX.) As the ram is raised, the pawl engages the ratchet-wheel and the mandrel is rotated through a portion of a revolution between each stroke of the forging-ram.

To enlarge a cylindrical hoop, such, for instance, as would be required for a cylinder lining, a hollow cylindrical mandrel of steel, h'', is employed, the ends resting upon suitable supports. The hoop is gradually enlarged upon the mandrel at each stroke of the forging-ram, which carries the swage block D^1. The cylindrical form of the forging is controlled by the workmen in accordance with the indications on the dial *f*, and the correct adjustment of the ram which rotates the mandrel h''. When a long cylinder is to be forged and drawn out, an apparatus, figures 2, 3, is necessary to move the short, hollow mandrel h'' as the work proceeds, and to withdraw it entirely when the hoop is to be re-heated.

The apparatus consists of a movable cylinder, *l*, open at one end and supported by the screw *m* from the carriage *n*. By the gearing *p* and the screw *m*, the cylinder can be raised or lowered to suit the different diameters of the



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The apparatus consists of a movable cylinder, *l*, open at one end and supported by the screw *m* from the carriage *n*. By the gearing *p* and the screw *m*, the cylinder can be raised or lowered to suit the different diameters of the

mandrels employed. The rod r is screwed into the end of the mandrel h'', after which the cylinder is brought up by the carriage on the rails x; the other end of the rod r is passed through the nose of the cylinder and through the piston q, the nut c'' being then screwed up to make the joint tight. By the admission of water into the space d'', the piston is forced out and the mandrel withdrawn. The nose of the cylinder l is made hemispherical, and is fitted into a loose cap v', which abuts on the end of the forging, and thus accommodates itself to any irregularity of the forging and insures that the strain of withdrawal will be applied in a direct line.

> "The Board witnessed the operations of casting followed by that of liquid compression, the enlarging of hoops, the drawing out of cylinders, and the forging of a solid ingot. The unanimous opinion of the members is that the system of Sir Joseph Whitworth surpasses all other methods of forging, and that it gives better promise than any other of securing that uniformity so indispensable in good gun metal.
>
> The latest exhibition of the wonderful character of the Whitworth steel has attracted great attention, and may be stated as indicating the present culmination of his success. From a Whitworth 9-inch gun, lately constructed for the Brazilian Government, there was fired a steel shell, which, after perforating an armor-plate of 18 inches of wrought-iron, still retained considerable energy. The weight of the shell was 403 pounds, the charge of powder, 197 pounds, and the velocity, about 2000 feet. The shell is but slightly distorted. The tests of the metal of which it was made show a tensile strength of 98 tons per square inch and a ductility of 9 per cent."*

Of these trials, the London "*Engineer*" of Aug. 24, 1883, has given the following:

In our correspondent's "Notes from Lancashire" last week, reference was made to a series of trials which have been made with a new 20-ton gun, built by Sir Joseph Whitworth and Co., of Manchester, for the Brazilian government, and he now sends us further details, which furnish a more complete description. The gun, which is one of a number ordered by the above government, is intended for the Brazilian man-of-war Riachuelo; it is made of Whitworth fluid-pressed steel, and consists of an inner tube surrounded by two series of hoops. The breech-action is that which is known as the French system, with a special arrangement applied by the manufacturers for opening and closing. The weight of the gun is 20 tons, and it has a bore with a maximum diameter of 9.05 inches and 29 calibers in length, rifled on Sir Joseph Whitworth's well-known system. This system of rifling is hexagonal in form, and for it it is now

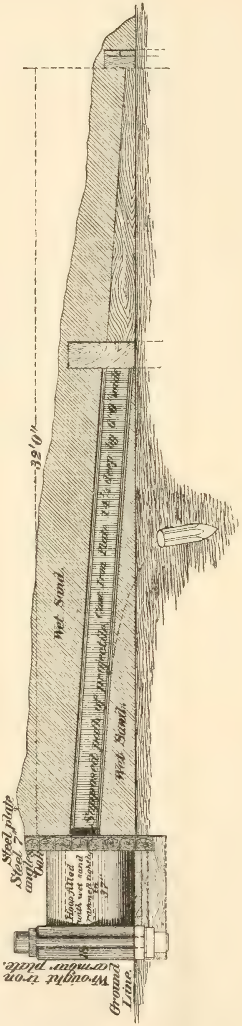
* Gun Foundry Board Report.

claimed as an advantage over other forms that with the introduction of a special gas-check the projectiles are now used as cast and require no tooling. The hexagonal form of projectile, it may be added, does not depend on the gas-check for rotation, and there is no danger of its stripping as is sometimes the case with projectiles that have to depend for their rotation solely upon the gas-check. It is also well known that a gas-check does not in all cases entirely prevent the escape of gas past the projectile, and when this is the case erosion must inevitably commence, which ultimately will tend to destroy the fine lines of any polygroove system of rifling. The special advantages claimed for the hexagonal bore, it may be stated, are that with its well-rounded corners it is stronger in form and much less liable to fracture and damage, or to deterioration from corrosion when neglected, and that with its positive rotation a quicker pitch of rifling may be employed, whilst it enables a longer projectile to be used or fired, which is a point of considerable importance when the shot or shell is required for the piercing of armor plates. With regard to loading, any difficulty which might arise with the hexagonal form of projectile is overcome by the use of guides, and, as all breech-loading guns have now enlarged powder chambers, a guide to carry the projectile through the chamber is necessary. If, therefore, the guide is made of the right form, the hexagonal projectile can be loaded as easily as one of cylindrical shape. It is not necessary to refer at any greater length to the special construction of the gun, and, passing on to the results obtained, as shown by the series of trials it has undergone, they may be said to have been of a highly satisfactory character throughout. The trials have been carried out at Blackley, near Sir Joseph Whitworth and Co.'s works, and on the Birkdale Sands at Southport, and the results of each trial are given in tabulated form below:

Round.	Powder charge, lbs.	Velocity, feet per second.	Projectile.	Result.
1	122	1872	Solid shot, 321 lbs.	
2	150	1982	"	
3	175	2096	"	
4	160	2027	"	
5	160	2003	"	
6	160	1988	"	
7	171	2074	"	
8	181	1989.9	Common shell, 300 lbs. empty.	10 deg. elevation, range, 7876 yards.
9	194½	1897.9	Solid shot, 400 lbs.	0 deg.
10	197	......	Steel shell, 403 lbs. empty.	Fired at and penetrated 18-in. wrought-iron plate and backing.

It may be added that during the various trials the pressure in the powder chamber ranged from 12½ to 17 tons, according to the charge used.

TRIALS WITH WHITWORTH 9-INCH B. L. R.



TARGET AND BACKING AS FIRED AT.


403 LBS.

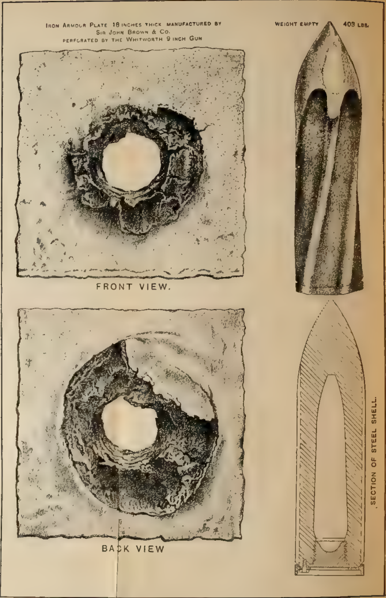
The gun was fired at a distance of about 90 feet from the face of the target, and the velocity, judged by the result obtained by the previous shot fired under practically the same conditions, would be about 1900 feet per second.

The target (Plate XXX.) consisted of a solid wrought-iron plate 18 inches in thickness, of very good quality, manufactured by Messrs. John Brown and Co., of Sheffield. In the rear of the plate was a backing composed of a steel hoop 37 inches long with a 23-inch hole, and rammed hard with wet sand; then a second backing composed of a T-iron riveted on to a steel plate 1⅛ inches thick and built in solidly with oak; this was further supported by a cast-iron bed-plate 20 feet long by 5 feet wide and 14½ inches deep, and finally securely strutted by a series of timbers firmly driven into the sand, the whole being covered over with wet sand to a height of six or seven feet.

The shell—9 inch diameter and manufactured of Whitworth steel—made a clean penetration through the plate (Plate XXXI.), and in its further passage burst in two pieces the steel hoop, passed through the backing composed of a 1⅛-inch plate and oak planks bolted on with T-iron, broke into fragments the cast-iron bed-plate supporting the backing, and finally buried itself in the sand at a distance of 17 feet 6 inches from the face of the plate, and at a depth of 4 feet below the cast-iron plate. The shell (Plate XXXI.) when dug out was found to have sustained comparatively little injury, except that it had been somewhat shortened at the extremity, and a slight twist had been given to the pointed end.

The London *Times* of September 1, 1883, in a leading article, points out the excellent character of the Whitworth armor:

As far as Woolwich and Elswick are concerned, we have not heard of any remarkable achievements in the way of strengthening either the attack or the defence; and the actual performances of the service guns are seldom disclosed by the authorities, who are responsible for their construction. It is said, however, that the Woolwich 80-ton gun has not yet succeeded in sending any projectile through so much as sixteen inches of wrought-iron, and that a ship carrying this thickness of armor would be tolerably safe as far as regards our own artillery. Such a result cannot be regarded as final; for, a week or two since a 9-inch, *i. e.*, about a 20-ton gun, constructed by Sir Joseph Whitworth for the Brazilian government, was fired experimentally at Southport, and sent a steel shell weighing 403 lbs. through eighteen inches of wrought-iron, thirty-seven inches of wet sand, hard rammed into a cylinder, which was split open, one inch and an eighth of steel, various balks of timber, and about sixteen feet of sand, the projectile being picked up uninjured, except for a slight distortion of its tip. A fortress armed with guns of this description, to say nothing of larger and more powerful ones upon the same principle, would be an exceedingly formidable adversary; and it is probable that any ships which might engage it would be compelled to sheer off to repair damages long before they could make any impression upon its defenders. The inventor of the gun does not despair of being able to provide means of protection against it, and is of the opinion that an armor plating of compressed steel, built up of segments in such a manner as to prevent the extension of a split or crack beyond the limits



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As far as Woolwich and Elswick are concerned, we have not heard of any remarkable achievements in the way of strengthening either the attack or the defence; and the actual performances of the service guns are seldom disclosed by the authorities, who are responsible for their construction. It is said, however, that the Woolwich 80-ton gun has not yet succeeded in sending any projectile through so much as sixteen inches of wrought-iron, and that a ship carrying this thickness of armor would be tolerably safe as far as regards our own artillery. Such a result cannot be regarded as final; for, a week or two since a 9-inch, *i. e.*, about a 20-ton gun, constructed by Sir Joseph Whitworth for the Brazilian government, was fired experimentally at Southport, and sent a steel shell weighing 403 lbs. through eighteen inches of wrought-iron, thirty-seven inches of wet sand, hard rammed into a cylinder, which was split open, one inch and an eighth of steel, various balks of timber, and about sixteen feet of sand, the projectile being picked up uninjured, except for a slight distortion of its tip. A fortress armed with guns of this description, to say nothing of larger and more powerful ones upon the same principle, would be an exceedingly formidable adversary; and it is probable that any ships which might engage it would be compelled to sheer off to repair damages long before they could make any impression upon its defenders. The inventor of the gun does not despair of being able to provide means of protection against it, and is of the opinion that an armor plating of compressed steel, built up of segments in such a manner as to prevent the extension of a split or crack beyond the limits

of the segment in which it was produced, would suffice, not only to resist, but even to break up any projectiles of an ordinary character. It will be remembered that a heavy shell, fired experimentally against a target of this description, produced no further effect than a shallow and saucer-like excavation on its surface; and it is probable that the extreme firmness of the compressed steel would be such as to afford its full degree of resistance to impact by the use of smaller thicknesses, and consequently of lesser weights, than are required in the case of a less dense material. On this point, however, not only to establish the principle, but also in order to discover the practical limits of its application, further experiments are needed; and it can hardly be said at present that we possess, or at least, are in a condition to employ, any armor which will render the fleet invulnerable to guns well served from fortresses.

The following extract from a lecture delivered at the Royal Artillery Institution, by Capt. C. Orde Browne, and reported in the Proceedings of the Royal Artillery Institution, for December, 1883, will illustrate his estimate of the Whitworth steel shells:

You see before you an actual Whitworth projectile and a Terre-Noire projectile fired by the sub-committee here. There is a great difference between the two shots. This Whitworth shot was an extraordinary projectile; it was fired twice at 12 inches of iron, and that projectile has passed twice clean through 12 inches of iron. Major Hime obtained authority to take it, and we discovered it in the range. It was just going to be sold as old metal; we fished it out from under some old metal and got it up here. Having identified and exhibited it, the claims of the projectile were questioned by the committee. But its history can be certainly traced out. It had no sooner established its claims than while at the Royal United Service Institution, it was carried off to Shoeburyness. However, Major Hime rescued it, and there it is. It is a notable projectile. I do not suppose, unless Krupp has one, that there is a shot anywhere that has done so much work; and it appears capable of repeating it. *This* is a Terre-Noire projectile; it is made of steel, and you see how much it is set up. If the projectile set up in that way against wrought-iron, it would set up a great deal more than that against the magnificent Schneider steel. The Whitworth shot is made for the 100-ton gun, and this shot for the 9-inch. It is a great deal more difficult to make equally good shot for the 100-ton gun than for the 9-inch, and yet the Spezia projectile is enormously beyond this Terre-Noire in merit. . . . . At this moment our ships are furnished with chilled projectiles, which are very good against wrought-iron; but I believe they would not be good against steel-faced armor, and perhaps they would be worse than almost any projectile carried by any foreign ships if they were fired against chilled armor, because in this they can make no hole, but merely break it in pieces. In 1879, some of us saw an experiment carried out at Meppen, the full significance of which I did not see at the time. Krupp had made what he called a Gruson chilled-iron shield, and he made a wrought-iron shield of his own to compete against it. He began by firing chilled-iron shot at both, but he was shrewd enough to perceive that his rival's shield, even when made by himself,

was likely to do better than was desirable under these conditions; for the chilled shot broke with little effect on the former, while they cut deep into the latter. That would show that even foreign chilled shot are bad against chilled-iron; and I should think ours are perhaps worse. The Whitworth have proved themselves the best steel shot, but Sir Joseph Whitworth refuses to make any more for us at present, and so does Krupp. At this moment we are badly in want of steel shot. The expense of developing steel shot is getting plates to try them on; and if the Admiralty try a great number of plates from time to time, it seems a pity to go on testing them with chilled shot which have been declared to be useless against them. I hope they will shortly try steel shot instead. It is a serious feature that we are not more forward in the manufacture of steel shot. At this moment the steel-makers tell me that they do not want to try 12-inch shot, but they want to try 9-inch shot. So that you can hardly say that we are in a position to make such shot as that for the 100-ton gun, unless Sir Joseph Whitworth would make them for us.

Bessemer Steel Works, Sheffield.—The manufacture of steel as treated in the Bessemer converter came under the particular notice of the Board at the works of Sir Henry Bessemer, in Sheffield."*

Lieutenant Chase gives the following description of the English converter:

The English converter (Plate XXXII.) resembles a retort with a broad paunch and a very short and wide neck which will not be liable to become choked. It is closed by plates of iron riveted like those of steam boilers, and is lined inside with well-rammed refractory earth A, called *ganister*, the thickness of which varies from five to eight inches. At the height of its center of gravity, it is embraced by an iron or steel belt B, which carries two trunnions C, resting upon standards D. One of these trunnions carries a cog-wheel E, on which a toothed-rack F acts, actuated by the piston of a horizontal hydraulic cylinder, so that the converter may oscillate freely around the axis of the trunnions. An air-chamber G, of cylindrical shape and small height, is permanently fixed to the lower part of the converter. The air is made to reach the chamber at its bottom I, through the center of one of the trunnions and through the curved pipe H, which runs along the side of the converter. The blast reaches the trunnion by a suitable pipe L, and is usually shut off by an independent valve.

The converter having been brought into a horizontal position, the molten cast-iron is introduced. The converter is then turned up into its vertical position, and as the liquid metal comes in contact with the tuyeres, the blast is turned on.

The tuyeres T lead vertically under the bath of cast-iron. They are of refractory brick and are slightly conical in shape. Each is pierced parallel with its axis by conical chambers about an inch in diameter, for the passage of air. The nozzles are set into the ganister lining of the bottom of the converter

* Gun Foundry Board Report.

Fig. 1.

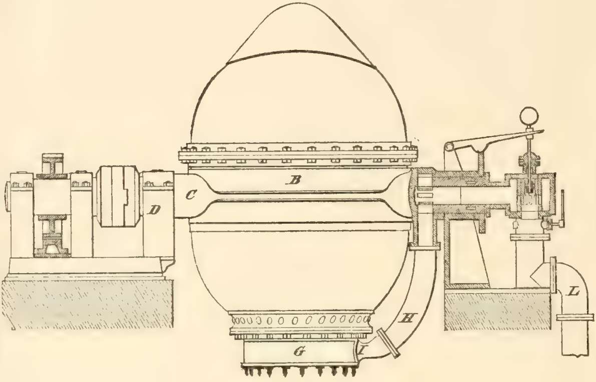
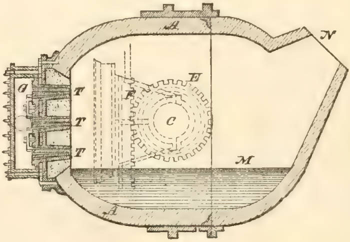


Fig. 2.



BESSEMER CONVERTER.

so as to come even with the surface. The blast is forced into the air-chamber by a blowing engine and has a pressure of about two atmospheres. When for charging or running off, it is desired to entirely stop the blast, the converter is brought into a horizontal position to prevent the molten iron from running into the tuyeres and air-chamber. For this purpose it is turned over on its most rounded side, the shape being calculated so as to contain all the charge without the level M of the liquid rising as high as the tuyere mouths.

When in operation, the converter should be vertical, and the mouth N leads into a basket funnel surmounted by a chimney.

About an hour before commencing the operation, the converter is heated with charcoal and coke in connection with a free use of the blast. When the proper temperature is reached, the converter is reversed and the fuel dropped out, when it is returned to a horizontal position to be charged with molten iron, which is brought either directly from the blast furnace, or a reverberatory. The converter is then righted and the blast turned on with full force. The whole duration of the operation varies, generally, from fifteen to twenty-five minutes, but is prolonged until the last portions of the carbon have disappeared. To the product pure cast-iron, *spiegeleisen*, in the fluid state is added, according to the composition of the steel desired, the converter being brought to a horizontal position as for charging. After having left the mixture to work some seconds, the converter is reversed so as to pour out the metal into a casting ladle, from which the casting is made in the usual manner.

> "At the Bessemer Works, nothing in the practice deserving of special remark was observed with the exception of the use of a mechanical stirrer, which is inserted into the molten metal in the ladle after the recarburating charge of spiegeleisen has been added. The stirrer is, in form, a two-bladed propeller on the end of a vertical shaft, actuated by a geared engine of 6 horse-power, conveniently placed at the side of the casting pit. The revolutions of the stirrer have the effect of more thoroughly incorporating the spiegeleisen with the charge, disseminating it throughout the mass."*

Of this mechanical mixer and its application, the inventor, Mr. W. D. Allen, Managing Director of the Bessemer Works, in an address to the Iron and Steel Institute, said:

The constantly increasing demand for Bessemer steel of high and uniform quality caused the writer's attention to be directed to the attainment of the perfect admixture and blending together of the different constituents; but notwithstanding the greatest care in the operation and in the selection of materials the results seemed to vary to an extent that was perplexing and unsatisfactory; continued attention convinced him that the want of uniformity arose almost entirely from the imperfect admixture of the carbon and manganese with the

*Gun Foundry Board Report.

converted metal. To overcome this difficulty he devised a mechanical agitator to revolve in the fluid metal beneath a covering of molten slag, and therefore out of contact with the atmosphere.

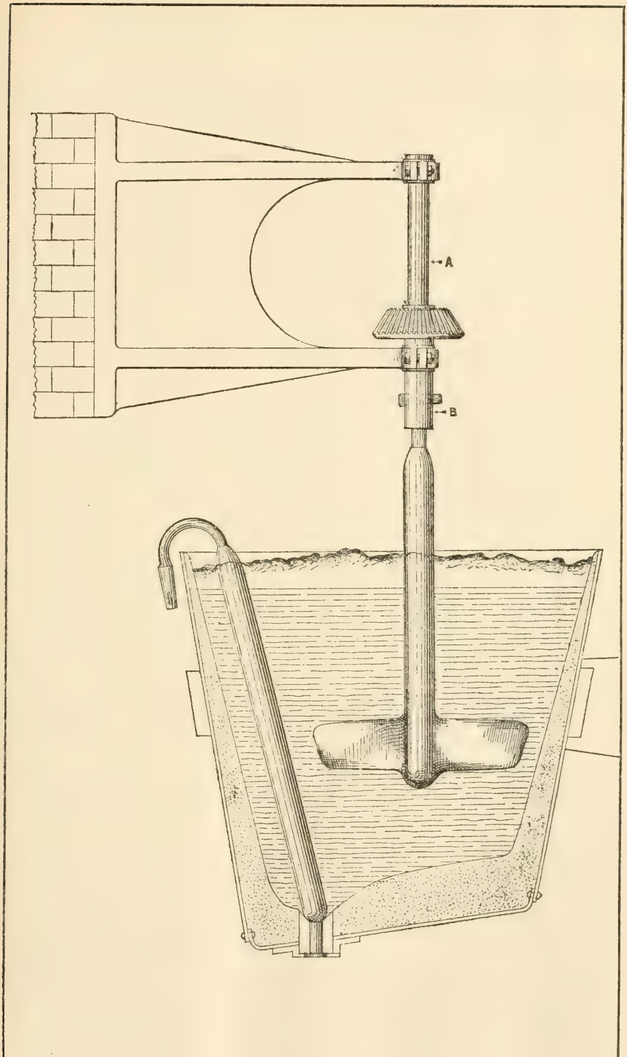
The stirring takes place in the ladle immediately before casting. The apparatus consists of a vertical spindle A (Plate XXXIII.), having at its bottom end a socket B. The spindle is supported in bearings, and is fixed at a convenient part of the pit where the ladle of steel can be brought by the hydraulic ladle crane beneath it, and is driven by bevel wheels and a horizontal shaft. The agitator itself is an iron rod about 1½ inches in diameter, one end slightly tapered to fit easily into the socket B, where it is held by a cotter, while the other end has a long slot punched in it to receive the blade of iron about 2 feet long, 4 to 5 inches wide, and ⅜ of an inch thick. The rod and blade are coated with ganister, thoroughly dried and blacked. The ladle of steel, immediately after pouring, is brought beneath the agitator and raised by the crane, immersing the blade and a portion of the rod. Rotary motion of about 100 turns per minute is then given to the agitator, the ladle being raised and lowered during the operation to insure all portions of the steel being acted upon. When the stirring is deemed sufficient, the ladle is lowered and the casting made in the usual way.

Besides the complete and reliable diffusion of the spiegeleisen, the liberation of occluded gases is a most important feature of its use, and with it sound castings, free of all honey-combing, and uniform throughout, are now made with perfect regularity and certainty by the Bessemer process.

One grand application of Bessemer steel has, of course, been for rails. So marvellous has been its success in that direction, and so persistently has it been turned to that use, that there sometimes appears a danger of this splendid material being neglected for other purposes, and its use for rails becoming its ultimate destiny.

It is an anomaly that when the charter was granted Bessemer for his wonderful process of converting iron, he should have been denied the right to manufacture that production—rails—for which Bessemer steel was so pre-eminently destined.

> " No product of the Bessemer converter has yet been found to answer all purposes for gun construction; it has been used with success for hoops for light guns, but it is deficient in the hardness required for tubes and has the reputation of want of uniformity. Extensive experiments were made in France several years ago with this metal, with a view to adopting it for gun construction, but failure after failure caused the abandonment of the effort. Those who are laboring to perfect this process insist that great improvements have recently been made, and that the character of want of uniformity is no longer deserved. Should final success attend these efforts, there will



ALLEN'S MECHANICAL AGITATOR.

be a probable future of great usefulness opened up for the numerous phosphoric ores in the United States, as the Bessemer converter is found to be a most convenient means of applying dephosphorizing elements to these ores when in a state of fusion.

Basic Process.—For the purpose of investigating this matter, the Board visited the extensive works of Bolckow, Vaughan & Co., near Middlesbrough, where, under the guidance of Mr. E. Windsor Richards, the manager, the manufacture by what is termed the 'Basic Process' was witnessed.

This immense establishment is located at Eston, 5 miles from Middlesbrough, and there is evidence of great executive ability guiding the details of its conduct. The company owns very extensive territory adjoining the works, and tributary mining districts of coal and ore, and employs fourteen thousand men. At Eston there are twenty-six blast furnaces: 11,000 tons of pig-iron are cast per week, and, in addition to other fuel, there is a weekly consumption of 13,000 tons of coke; 8000 tons of coal and 7000 tons of ore are raised per day.

One point may be mentioned in connection with the manufacture of steel rails at this establishment. The iron is not cast into pigs, but is carried direct from the blast furnace to the Bessemer converter; after casting, the ingot is removed at the earliest possible moment from the mould, and after a short re-heating is carried to the rolls, from which it comes out in the form of a finished rail, the whole operation being completed in one heat.

Ten Bessemer converters are in operation, six worked by the Basic Process and four on the usual Acid Process, with a siliceous (ganister) lining."*

The following extract from the London "*Engineering*" contains an excellent description of the Bolckow-Vaughan establishment:

The Cleveland Steel Works, as they are called, immediately adjoin the blast furnaces of the firm at Eston and South Bank, the latter range of furnaces being merely separated from the former by the Middlesbrough and Saltburn branch of the North-Eastern Railway, which passes between them, and is connected with the sidings of both the works. The works are also connected by

* Gun Foundry Board Report.

a private line with a fine jetty on the banks of the Tees, provided with ample appliances for the rapid unloading of foreign ores, &c., and for the shipment of rails. The steel works were commenced in 1876, shortly after the firm had resolved to give up the works which they had previously had at Gorton, near Manchester, while in the following year, 1877, the manufacture of steel by the Bessemer process was started. From the very first, the works were laid out with a view of converting the molten iron from the blast furnaces into steel rails by the aid of the best mechanical devices which experience and engineering skill could suggest, and as they have been enlarged, and developed, this end has been kept clearly in view, and nothing has been allowed to stand in the way of improvements. As a result, the works as they now stand are a magnificent example of modern practice, remarkable not merely for their vast size and enormous productive power, but also for the perfection of their details, and for the evidences on all sides of the enterprising skill and energy with which they are controlled.

The main buildings at the Cleveland Steel Works form a rectangular block made up of a series of parallel spans, the center lines of the spans being at right angles to the direction in which the materials pass through the works. Thus, commencing at the western end of the works, the successive spans may be considered as devoted to the successive operations which the material undergoes during conversion from the product of the blast furnaces into finished rails, while longitudinally the ranges of shops may be regarded as divided by an imaginary line into two parts, of which the northern is devoted to the manufacture of steel by the basic process, and the southern—and older—part to the acid Bessemer process.

At the time when the Eston works were planned, the basic process was unknown, and the plant was originally laid out for the ordinary Bessemer process, it being proposed to erect—as has since been done—two pairs of 8-ton converters. It will be remembered that in 1874, a warm discussion ensued as to the practicability and impracticability of the system of supplying Bessemer converters with molten iron direct from the blast furnaces, a mode of working which had been originally contemplated by Sir Henry Bessemer. At Barrow very strong opinions were expressed on both sides by men of high standing in the steel trade, and the balance of the evidence was decidedly in favor of the "direct process," as this method of working has been sometimes named. During the following years—1875–76—this system made steady advances in this country, and its advantages became generally acknowledged by our leading steel-makers. It was used by Mr. E. Windsor Richards at Ebbw Vale, by Mr. Snelus, at Workington, and by Mr. E. T. Smith—originally one of its strongest opponents—at Barrow, and in each case with most satisfactory results. When, therefore, the Eston Works were planned, they were laid out for this mode of working, Mr. E. Windsor Richards designing the arrangements for handling the metal.

These arrangements were adopted for the converters put up for carrying out the ordinary Bessemer process, and in principle they have been adhered to in constructing the plant for the basic process. The blast furnaces employed in

smelting iron for conversion into steel are raised, so that a line running on the level of the floor of the steel works can be carried through a tunnel which runs underneath the pig-beds. On this line run the trucks carrying the ladles by which the molten iron is conveyed to the converters, the iron being run into the ladles direct from the blast furnaces through openings in the top of the tunnel just mentioned. The pig-beds are only used for casting any iron which it may be necessary to run at times when the steel works cannot take it. The ladles containing the molten iron are hauled by small locomotives to the steel works, and then raised by suitable hoists to the level of the converter stages, along which they are run into the proper positions for pouring into the converters.

Messrs. Thomas and Gilchrist prepared for the Paris meeting of the Institute in 1878, a paper "On the Elimination of Phosphorus in the Bessemer Converter," this paper describing their earlier researches and experiments.

Although the paper was not read at Paris, yet at that meeting the subject was brought by Mr. Thomas before the notice of Mr. E. Windsor Richards, the manager of the Cleveland Steel Works, and Mr. Richards, appreciating its importance, very shortly afterwards arranged to give it a trial. After examining into what had been accomplished by Messrs. Thomas and Gilchrist at Blenavon and Dowlais, Mr. Richards put up a pair of experimental 30 cwt. converters at Eston, and then commenced an extensive series of trials—some successes and some failures—which tested the skill and perseverance of all concerned in them. It was not merely the details of the basic process itself which had to be worked out, but the difficulties of preparing and applying the basic materials used for the linings of the converters. At length the energy and persistence of those engaged in the development of the system were rewarded with success, and on April 4, 1879, two successful charges were worked in the presence of a number of visitors. Shortly after, one of the 6-ton converters at Eston was re-lined for the basic process and a fair degree of success was obtained with it.

The news of what was being done at Eston naturally created great excitement abroad, and from the United States, Belgium, Germany, France, and Austria, requests for further information poured in upon Messrs. Bolckow, Vaughan & Co., who had in many cases the most unreasonable demands made upon them. From that time to the present the practical details of the process have been steadily improved until, under the fostering care and energy of Mr. E. Windsor Richards, it has attained at Eston a grand development.

There are now at the Cleveland Steel Works six converters, each of 15 tons capacity, devoted to the basic process. These converters are disposed in two groups of three each, the whole six converters being in one straight line, and each group having in front of it a shallow double pit in shape somewhat like the letter ω, and provided with two hydraulic ladle cranes. The section of the building containing the converters and pits is spanned by steam traveling cranes by which converter-bottoms, &c., can be lifted and by which the charges of lime are brought to the converters in suitable iron hoppers. At the back of the converters and at a convenient height runs a charging stage, along which are conveyed to the converters in ladles mounted

on carriages, the charges of molten iron from the blast furnaces, and from which the converters also receive the additions of hematite and spiegel. The staging is provided with the necessary hoists, and behind it again is a space devoted to the preparation of the converter-bottoms, hoods, &c., the plant in this department including mortar mills for the mixing of the magnesian limestone with tar, large ovens for the firing of the bottoms, &c. The bottoms, we may mention, are rammed by hand, the men using red-hot bars for rammers, and the tuyere holes for the blast being formed by iron cores inserted in the mould. The material is well rammed around these cores, and the latter are as a rule knocked out before the bottoms are fired.

Returning to the front of the converters, it will be readily understood that by the arrangement of ladle cranes above mentioned, either crane can command two converters. The processes of pouring from the converter to the ladle, and the subsequent teeming of the steel into the moulds, are the same as in the ordinary Bessemer process, but the quantity of slag to be dealt with is much greater—being about one-third the weight of the steel—and it is the practice to pour off a great portion of this slag from the converter immediately after the "after-blow," as it is called (this being the name given to the part of the blowing which lasts after the elimination of the carbon), and prior to the addition of the spiegel.

The rail ingots cast are 15½ inches square, and vary in weight from 1¼ to 1½ tons, according to the section of rail to be rolled. As soon as possible after teeming, they are taken from the moulds, placed on trolleys and run off by small locomotives, running on lines of 3-feet gauge to the range of Siemens gas-furnaces, where they are wash-heated, or rather where their heat becomes equalized throughout, the amount of real heating done in these furnaces being comparatively small, and there being, it must be borne in mind, no subsequent heating whatever.

After having remained a sufficient time in these furnaces, the ingots are drawn out by a very simple arrangement of hydraulic gear, each ingot as drawn being received by a trolley, which is at once towed off by one of the small locomotives to the cogging mill.

From the cogging mill the bloom is conveyed to a powerful horizontal shearing machine, where it is cropped and delivered on to a narrow-gauge trolley placed on a line below the level of the floor of the mill. One of the small locomotives running on a parallel line of rails is then attached to this trolley and tows it up a short gradient to the mill floor level, and runs it along at great speed to the finishing mill.

Rails 150 feet long, or upwards, are dealt with at Eston with as much ease as shorter lengths. The time occupied in making the 12 passes through the roughing and finishing rolls being 80 seconds only. As a matter of fact, we believe that over 400 tons of rails have been produced in a ten hours' shift at this mill.

So far we have been speaking of the basic side of the works only. On the side devoted to the acid, or ordinary, Bessemer process, the arrangements are very similar. In this case, however, there are four converters of eight tons

capacity arranged in the manner to which we made reference in the early part of the present article. The cogging mill on this side, also, serves either of two finishing mills, these being driven by one engine situated between them Altogether about 5000 tons of Bessemer steel per week are being turned out at Eston by the two processes. In the completeness of their arrangements for the rapid handling of the material in the course of manufacture with the minimum of hand labor, the Cleveland Steel Works are probably unequalled in the world.

> " In the Basic Process the converter is lined with a mixture of dolomite (magnesia limestone), calcined, pulverized, and incorporated with coal-tar to make it pasty. The converter is taken to pieces and lined with this mixture 18 inches thick. Before lining the bottom, through which are the perforations for the passage of air during the operation of blowing, long rods are inserted in the holes, and the mixture is packed around them. When this operation is completed, the rods are removed, leaving holes through the bottom lining. The pieces of the converter are then assembled, and a fire is lighted on the inside to burn out the coal-tar on the inner surface; the whole lining then has a set. One lining of the sides is good for 40 or 50 blows; one lining of the bottom is good for 10 blows."*

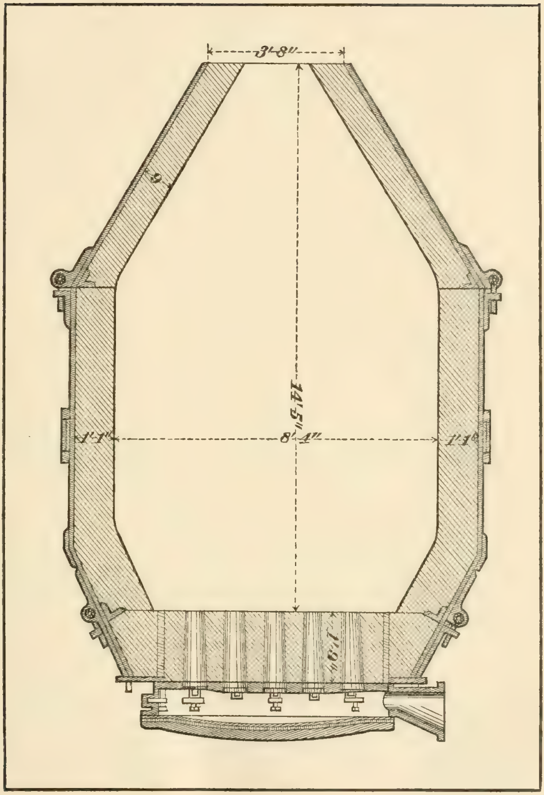
Holley has given the following description of the converter and lining:

The vessel is concentric, the nose being central and upright when the vessel is blowing. The internal diameter is 8 feet 4 inches, and the internal height 14 feet 5 inches. There are 21 tuyeres of ordinary size. The vessel is rotated by an hydraulic engine, acting through a worm wheel on the trunnion. It is divided into three sections, to be removed; the bottom, the cylindrical center, together with the trunnion-ring and pinion, and the conical nose. The bottom is removed by a ram, on a car. The two parts of the shell are each raised by overhead cranes, traversed out into the pit, lowered to a car and withdrawn to the rear.

About half the thickness of the lining, next the shell, is rammed material; the inner half is brick. The rammed material for both linings and bottoms is dolomite, burned in a cupola, as hard as possible by 1800 pounds of coke per ton of burned stone. After the bed charge of coke, the limestone and coke are thoroughly mixed. The calcined stone is ground and mixed with 10 per cent of coal tar. About 100 pounds of material are at present (1881) used for linings and bottoms, per ton of steel.

> " The converter being in place and heated, a charge of pure common lime, unslacked, is introduced (15 per cent of the

* Gun Foundry Board Report.



CONVERTER WITH BASIC LINING.

charge of iron). The molten metal, brought from the blast furnace, is then poured in and the blow commenced. When the phosphorus is removed, which is ascertained by mechanical tests, about three-fourths of the charge is emptied into the ladle, in which ferro-manganese has been previously placed; a charge of 4½ per cent of molten hematite, imported from Spain

and containing from 2½ to 3 per cent of silicon and a mere trace of sulphur and phosphorus, is then brought from a cupola furnace and poured into the ladle, causing a violent ebullition; this goes on for a time, more ferro-manganese being added, if necessary, to prevent red-shortening. When the boiling ceases, 4½ per cent of spiegeleisen is poured into the ladle, which is then brought again under the converter and receives the rest of the charge. The casting is then made from the ladle.

The ore used in this process is of very inferior quality; it is called Cleveland stone, has 42 per cent of iron and high phosphorus, the pig containing 1½ per cent. Being very low in silicon, it does not destroy the lining, which would be the case if silicon was high. The object of the lime is to take up and hold the phosphorus in the slag. The phosphorus is increased in the charge by adding some of the old slag, making the proportion of phosphorus 1.75 per cent. The amount of silicon in the iron is from 0.75 to 1 per cent. During the operation of blowing, this silicon is the first to disappear; the carbon is then consumed, immediately after which the phosphorus passes into the slag. This operation requires about 2½ minutes, and is timed from the moment the collapse or falling of the flame shows that the carbon is burned out.

Mr. Richards stated that previous to the introduction of the charge of hematite during the operation there was a want of uniformity in the results; that sometimes there would remain traces of phosphorus, but that the introduction of the pure hematite, which has only a trace of phosphorus and is high in silicon, before casting gives such stability to the mass as to prevent the slag from parting with any of the phosphorus it has taken up; the silicon also in the hematite is oxidized in calming down the steel, and it also goes into the slag. The introduction of the hematite also makes it possible to halve the ordinary charge of spiegeleisen, which, as spiegel is costly, cheapens the operation.

The Basic Process, thus briefly sketched, has for its object the utilization of inferior ores. It is the only one now known by which this injurious element, phosphorus, can be eliminated. For guns, the natural prejudice would be against metal made from ore which was originally defective, but the operators of this system hold that their product is as good as if made from

> pure ore. Whether it will ever be used for gun metal will depend upon the confidence that it may inspire in the future, but the problem of its application for general purposes has been successfully solved."*

The various intelligent opinions expressed as to the relative economy and quality of the productions of the basic and acid processes, render it extremely difficult to pronounce which possesses the greater merit.

The basic process has been introduced into Russia, and there employed in connection with both the Siemens furnace and Bessemer converter. It has obtained a strong hold in France, Austria, and Belgium, and, while the practice varies in different works, and samples and analyses from the same works do not agree, yet it is, on the whole, considered about as uniform as the acid process.

The quality of the soft steel is superior, and it is the remarkable purity and mildness, which, with the cheapness (because cheap ores can be utilized), is likely to give the basic steel an enormous use for boilers, ships, bridges, and all structures requiring toughness. It seems also to fulfil all the requirements for rails, tires, and axles.

On the other hand, it is held that the vulnerable point of the process is, undoubtedly, the relatively small durability of the refractory linings. It is probable that the cost of conversion in the basic process will always be somewhat higher than in the acid process, and on this account the pig-iron employed for the former should be, at least, so much cheaper than that used for the latter as to pay for the cost of the lime additions, and for the expense of handling both these and the greater bulk of slag produced, and also for the somewhat increased waste, and for the present, at least, larger consumption of refractory material.

The process has been very carefully tried at Creusot in the open-hearth furnace and Bessemer converter. The best results were obtained from the latter, but neither was considered economical; and as many of the railway companies refused, through prejudice, to receive rails manufactured by this process, the furnaces were stopped.

Mr. Ellis, of Sheffield, did not succeed during his experiments, in producing uniform metal, but in Germany there are several works using the process largely.

In the hands of Mr. Windsor Richards, it has been made a great success, and the iron mines of Cleveland, which suffered a temporary check through the universal susperseding of iron by steel rails (which

* Gun Foundry Board Report.

require pure ore for their production by the acid process), are in a fair way to receive a development greater than ever, thanks to the de-phosphorizing process brought into practical working by Messrs. Thomas and Gilchrist, and so ably extended by Mr. Richards.

The process has been worked to some extent in the United States, but the patents are now reported to be held by a syndicate to prevent the use of phosphoric ores in certain districts.

It was suggested to the Army Ordnance Board for use in the manufacture of large cannon, but as the Government was asked to expend more than $1,000,000 for a suitable plant, the suggestion was not received with favor.

PRESENT CONDITION OF THE ENGLISH ARTILLERY.

> "It is well known that the essential characteristics of the Woolwich gun were that it was a muzzle-loader and depended for its strength upon wrought-iron coils. The security of muzzle-loading and the safety derived from the wrought-iron used in the construction of the gun have been claimed as advantages over other constructions.
>
> At the time of the visit of the Board to England it was found that a great change had taken place in the opinions of the English artillerists on these two points, and that the military and naval services were changing the character of their armaments. The first effort was directed to the substitution of the breech-loading system. This was induced by the increasing difficulties attending the loading of large guns at the muzzle both on shore and at sea. Adherence to the practice of muzzle-loading had imposed much additional expense for machinery necessary for manipulation, and the ever-increasing length of guns and weight of projectiles complicated the difficulties. It was determined that attention should be given to the question of applying the breech-loading principle to guns, and in 1879-'80 plans were made for such constructions, and the experiments were inaugurated which promise to involve an entire change in the armament of the country.
>
> Although the idea of introducing the system of breech-loading seems to have been forced by the difficulties attendant upon the use of large calibers, the effort is now being made to apply the change to all calibers. The Board found that in the gun factory at Woolwich, guns of all calibers were being fitted on the breech-loading system.

One of the first experiments tried was with a 12-inch 43-ton gun, manufactured at Woolwich, which was built of wrought-iron coils and fitted with the French fermeture, necessarily inserted in the rear of the steel tube. Good ballistic results were obtained, but the construction of the gun does not seem to have given satisfaction. At the same time some experiments with 6-inch breech-loaders were carried on. These were built up in the same way; several failed, some of them after being fired with battering charges. The reasons assigned refer to bad metal and to errors in manufacture. These failures, however, seem to have convinced the authorities that it was not wise to continue the use of coiled wrought-iron hoops and breech-pieces, and the Board finds that with the adoption of the system of breech-loading there is a positive move to the use of steel for all parts of their gun construction.

The guns under construction at the Woolwich Gun Factories indicate that this conclusion has been accepted by the Government, though the differences perceptible in some of them show the gradual growth of the developed idea. For example, though the 12-inch 43-ton gun of latest order is composed entirely of steel, there are other guns of the same caliber and weight which have a portion of their hoops made of wrought-iron coils. There is no doubt, however, that the use of wrought-iron and the system of muzzle-loading have been abandoned." *

The new 43-ton breech-loaders are intended to supersede gradually the 38-ton muzzle-loaders. They are of 12 inches caliber and 27½ feet long. The projectile weighs 700 lbs., and the charge will be between 250 and 300 pounds. For service on shipboard the guns will have no trunnions, but will be supported in their carriages by close fitting bands, the under section of the hoop, corresponding to the trunnion-band, having four square-cut rings, which seat in a grooved block of the carriage. By this means much space is saved, particularly when mounted in turret, where the guns can be brought close alongside of each other.

"In addition to the 12-inch 43-ton steel guns, there are in hand 13-inch 62-ton steel guns; also 10-inch 26-ton steel guns designed to throw a projectile of 500 pounds with an initial velocity of 2100 feet. Much interest is also felt in the success

* Gun Foundry Board Report.

of the 9.2-inch 18-ton steel gun, which is designed to supersede in sea service the present 10-inch 18-ton wrought-iron muzzle-loader."*

It is 26 calibers long, has a charge of 105 pounds, a projectile of 320 pounds, and a muzzle velocity of 2046 feet with a pressure under 15 tons. The total thickness of metal over the chamber is $13\frac{1}{4}$ inches. The breech-mechanism engages in the jacket, which is 4 inches thick. The tube is $4\frac{1}{2}$ inches thick over the chamber.

"Four 8-inch $11\frac{1}{2}$-ton steel guns are being manufactured in the Royal Gun Factories; two of them will be 30 calibers in length and two will be 26 calibers in length, the shorter being intended for sea service. Breech-loading guns of 6-inch, 5-inch, and 4-inch calibers are also now constructed of steel.

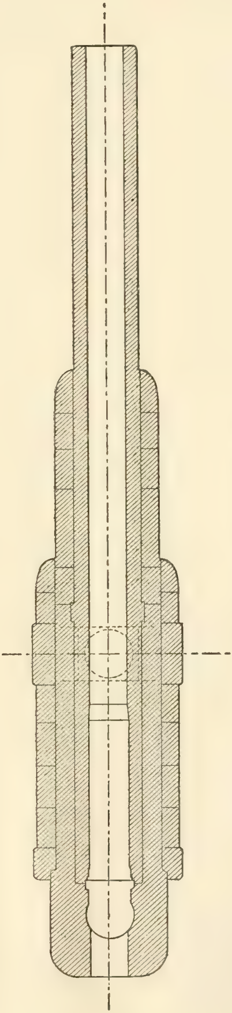
In this transition from wrought-iron to steel it must be particularly noted that the change as thus far made in large guns consists in the substitution of coiled steel for coiled wrought-iron; the reason for taking this intermediate step being the want of experience at the Royal Gun Factories in the manufacture of solid steel hoops, and the greater certainty of the manufacture of the steel coils. The superiority in strength of the steel coil over that of wrought-iron is positively claimed by the superintendent. Jackets (breech-pieces) and hoops of forged and rolled steel are to be used as soon as practicable.

What has been recognized by the world as the Woolwich system no longer exists in practice. In its place we find the Vavasseur design (Plate XXXIV.), a gun composed of a steel tube, with a steel jacket (breech-piece) supplemented by superimposed layers of steel hoops. This change has been brought about by public opinion, which has asserted itself in condemnation of the material and the system of construction so long in use.

Material.—It is stated by a very high authority that wrought-iron welded into such large masses as are required for the Frazer system, loses its fibrous character and becomes highly crystalline.

The use of the coiled steel hoops, adopted as a temporary expedient at Woolwich, is objected to by high authorities, who, while allowing that steel of an extremely mild quality might be used for welded coils, say that it would be no better than

* Gun Foundry Board Report.



Scale ½ inch = 1 foot.

6-INCH 80-CWT. VAVASSEUR B. L. R.

iron, and that at the point of welding no greater strength than that due to iron can be obtained.

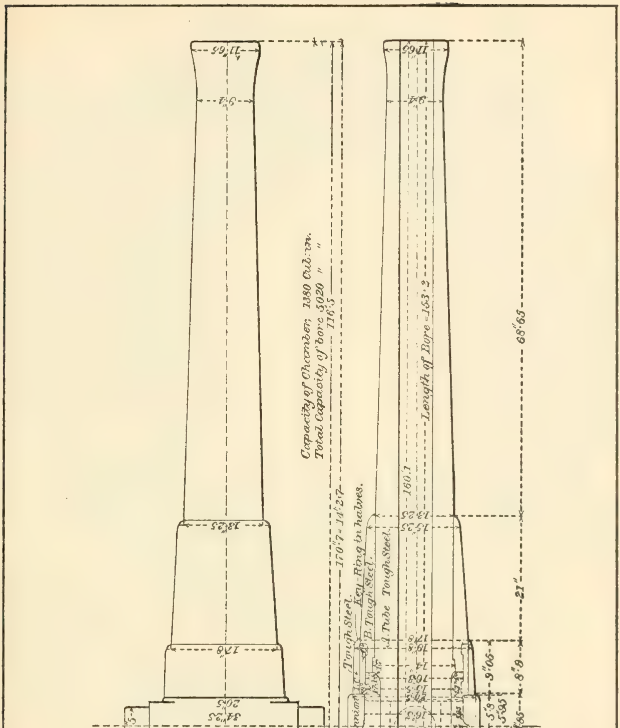
All authorities concur that steel, superimposed in layers over an inner barrel, is the best material for ordnance, and the preponderating testimony favors its manufacture by the Open-Hearth Process. This is not due to any objection to crucible steel, which has heretofore been used for all gun-tubes, but because the results of the Open-Hearth Process are equally satisfactory and cheaper. Even those who insist in retaining crucible steel for tubes are willing to adopt the open-hearth steel for jackets and hoops.

There is a difference of opinion as to the mode of manufacture of the hoops and jackets. All agree that small hoops should be rolled after having been forged into a ring shape from a cast ingot; but for larger hoops and jackets it is recommended by some that they should be cast hollow and then forged, and by others that they should be cut from a solid ingot and forged; while still another authority thinks that hoops and jackets of large size should be bored out of the solid after forging.

Construction.—In the latest designs for steel guns the system of Mr. J. Vavasseur has been adopted. This (Plate XXXV.) consists of a tube as thin as is consistent with strength; a long jacket shrunk on to provide longitudinal strength; and layers of superimposed cylinders or hoops shrunk on, the number of layers varying with the size of the gun. The thin tube develops more thoroughly the principle of a built-up gun, and is less liable to contain concealed defects. It makes the ultimate strength of the gun less dependent on its integrity.

Sir William Armstrong advocates a greater number of layers than Mr. Vavasseur or the superintendent of the Royal Gun Factories. The latter agree that the thickness of the layers should not be reduced to a point where the mass is not sufficient to compress the structure under it in process of cooling.

Sir William Armstrong considers that he increases the end strength of the layers of his guns by interposing sheet copper between the surfaces, and states that copper has been used in this way at Elswick for two or three years. The superintendent of the Royal Gun Factories and Mr. Vavasseur object to



6-INCH 89-CWT. MARK III, B. L. R.

the use of copper, as rendering the compression due to shrinkage uncertain in amount. They prefer to rely for end strength on hooking the layers together. In their latest designs the chase of the gun is not reinforced, but depends for its strength on the thickness of the steel tube. Sir William Armstrong, however, considers it desirable to extend the hoops to the muzzle of the gun to provide against the possible premature bursting of a shell in the bore."*

Plate XXXVI. presents the result of a most important and interesting experiment made by Sir Joseph Whitworth to illustrate the effective power of shrinkage. The ring was made of mild, fluid-pressed steel, and was heated and shrunk on to a plug 18 inches in diameter. When cold, the plug was forced out by an hydraulic pressure of 3200 tons.

The experiment thoroughly proved the union of the two parts, and is an excellent test of the merits of shrinkage without the interposition of any other metal.

Sir Joseph advocates the perfect machining and measuring of the portions to be assembled, and, with Dr. Siemens, believes it is of the utmost importance that the temperature to which the hoops are raised should be adjusted with the greatest nicety.

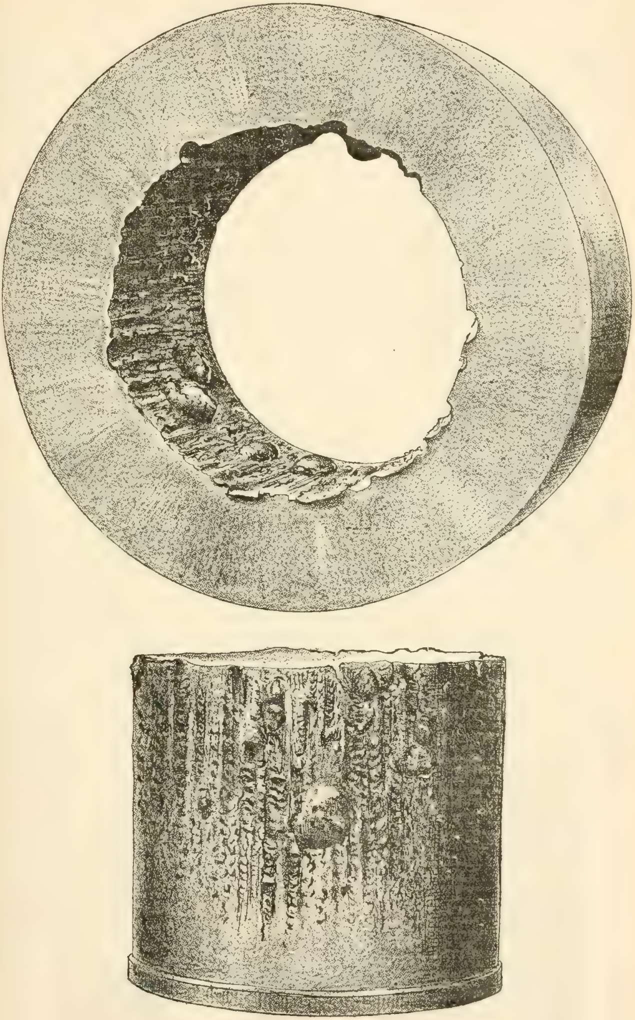
"The *pressures* to which the guns will be permitted to be habitually subjected will not exceed 18 tons to the square inch.

The propriety of lining the tube with a thin steel lining, is being closely considered for the purpose of providing a plan for renewing the portions of the metal scarred by firing, without having to resort to re-tubing. There is no doubt that experiments will be made in this direction.

Breech-Closing.—All the authorities in England now advocate the breech-loading system for cannon. The interrupted screw, commonly known as the French system (see page 749), is preferred, and has been adopted at Woolwich. In the heavier guns, at least, the breech-screw will not engage in the tube, but in the cylinder immediately surrounding it, thus relieving the tube from that portion of the longitudinal strain which tends to blow out the breech. The number of interruptions increases with the caliber; there are four in the breech-mechanism of the 12-inch 43-ton gun."*

The principal advantages of breech-loading are: It permits the projectile to be of the greatest possible diameter, secures accuracy of

* Gun Foundry Board Report.



SIR JOSEPH WHITWORTH'S EXPERIMENT SHOWING
THE EFFECT OF SHRINKAGE.

fit, and the best means of the application of the expanding material to take the rifling. Any sparks remaining in the bore can be easily and surely removed, thereby preventing a not unusual source of danger. Any injury to the vent can be readily repaired in the movable breech-piece. The gun can be more rapidly fired, and the fouling of the bore does not interfere with the loading. There is no danger of double shotting. The bore can be more readily inspected and any weakness more easily discovered. And, above all, breech-loading permits increased length of guns for use on board ship, and provides greater protection for the gunners.

The relative merits of the two systems of breech-loading and muzzle-loading are clearly and forcibly stated by Sir William Armstrong, in his address before the Institution of Civil Engineers in January, 1882, as follows:

The question whether breech-loading or muzzle-loading guns are most advantageous is one which has been discussed in a very uncompromising spirit, as if one or other of the two systems ought to be universally adopted, to the entire exclusion of the other. Impartial consideration, however, will show that there is room for both systems, and that each is best in its proper place. It has been distinctly proved that, so far as accuracy and velocity are concerned, there is nothing to choose between them. Neither is there any material difference in regard to rapidity of fire; nor would a superiority in this respect on either side be of much value, seeing that it is of far more importance to cultivate careful and deliberate fire than to facilitate a lavish expenditure of the very limited supply of costly ammunition that can be assigned to each gun in active service. With regard to convenience of loading and security of the gunners, the advantage is in most cases, though not in all, on the side of the breech-loader. Guns mounted on the broadsides of ships or in casemated batteries cannot be loaded at the muzzle by any known method without very seriously exposing the men to the fire of machine-guns and small arms. In fact, the great length of modern guns renders it impossible to get access to the muzzle for the purpose of loading without allowing more space for recoil than is practicable in a ship, or in the usually confined space of a casemate; so that in these cases breech-loading must be regarded as a necessity. But in earth-work batteries a muzzle-loading gun can, by proper arrangement, be loaded under shelter of the parapet more securely and quite as conveniently as a breech-loader. In revolving turrets, also, a gun may be loaded at the muzzle by external means, involving no exposure of the men, and in gun-boats carrying a heavy gun on the line of the keel, loading at the muzzle is also easily effected.

The superior simplicity of a muzzle-loading gun entitles it to a preference wherever it can be used with equal advantage. All breech-loading mechanism is of a nature to require very accurate fittings, such as require care both in use and for preservation. Breech-loaders, therefore, are very unfit weapons for imperfectly instructed gunners, and they are quite out of place in open batteries

where they would be exposed to the injurious influences of the weather and of drifting sand. It would be folly, therefore, in such cases to use them in preference to muzzle-loaders, which require little care for their preservation and take no harm from exposure.

Of breech-fermetures and the part of the gun into which they should engage, Colonel Crispin, U. S. A., gave as his opinion :

Regarding the systems of breech-closing, the round wedge and the slotted-screw plug fermetures are the only two modes known to the civilized world which have been thus far thoroughly perfected, and as they both meet excellently well all the requirements of a good breech-closing arrangement, and as it is hardly possible to suggest anything superior in simplicity and effectiveness, it was thought unnecessary to make any additional researches looking to the presentation of other systems. One feature in the construction of those plans which involve the use of interior tubes is important, and to it attention is especially invited. It is the relief of the interior tube from longitudinal strain, the breech-block in every instance working in the steel breech-receiver, and the longitudinal stress being primarily applied entirely to the latter and transmitted hence, however, to the cast-iron casing. The interior tube being thus unclosed at the rear end, has, besides the tangential strain, only a longitudinal stress to the front, produced, principally, by the powder gases operating on the shoulder of the chamber and the friction occasioned by the passage of the projectile through the bore. It is hence not subjected to the pulling-apart tendency which arises in those constructions, such as the Woolwich and Armstrong, where the interior tube receives the breech-mechanism and thus closes the tube, in the act of firing, at the rear. The 100-ton Italian gun (Armstrong manufacture) which burst on board of the Duilio, was so constructed, and its thick steel interior tube closed at the rear by the breech-plug gave way, below the shoulder joining the bore and chamber, and carried with it, to the rear, sections of the shrunk-on wrought-iron jackets ; these latter so connected together as to afford but little longitudinal support, and hence throwing almost the entire strain on the interior tube. Consequently, I give decided preference to plans in which an interior lining-tube, *disconnected* with the breech-mechanism, finds place.

There has been much discussion as to whether the slotted-screw fermeture is more liable to be disabled by projectiles than the wedge. Both are much, and apparently equally, exposed when open for loading, but are somewhat protected by the breech-hoops.

The wedge system has the advantage of having been tested in service, and a just comparison cannot be made until the slotted-screw has had as thorough an opportunity to prove its fitness.

Gas-Check.—The de Bange gas-check (see page 750) has been adopted at Woolwich and is preferred by Mr. Vavas-

seur. It is considered as complying more nearly than any other with the conditions required of a perfect gas-check. It requires no seat to be prepared for it in the chamber, is not liable to derangement, and does not require perfect accuracy in its manufacture. Sir William Armstrong adheres to the Elswick cup, as opposed to the Broadwell ring, and objects to the de Bange gas-check because of the additional length of gun required; in the 12-inch 43-ton gun this amounts to 6 inches.

Vent.—The vent is in the axis of the gun, and the escape of gas through the orifice, after firing, is checked by a device by which a plug is drawn into the neck of the primer by the action of pulling the lanyard attached to the friction tube.

Form of Chamber.—At the Royal Gun Factories it is considered that the best results are obtained with chambers not more than 3½ diameters in length, and with an opening the full diameter of the chamber. Sir William Armstrong, though preferring a long, narrow chamber as being favorable to strength of tube, thinks that under the present aspect of the powder question the short, wide chamber, with full-sized opening, must be adopted."*

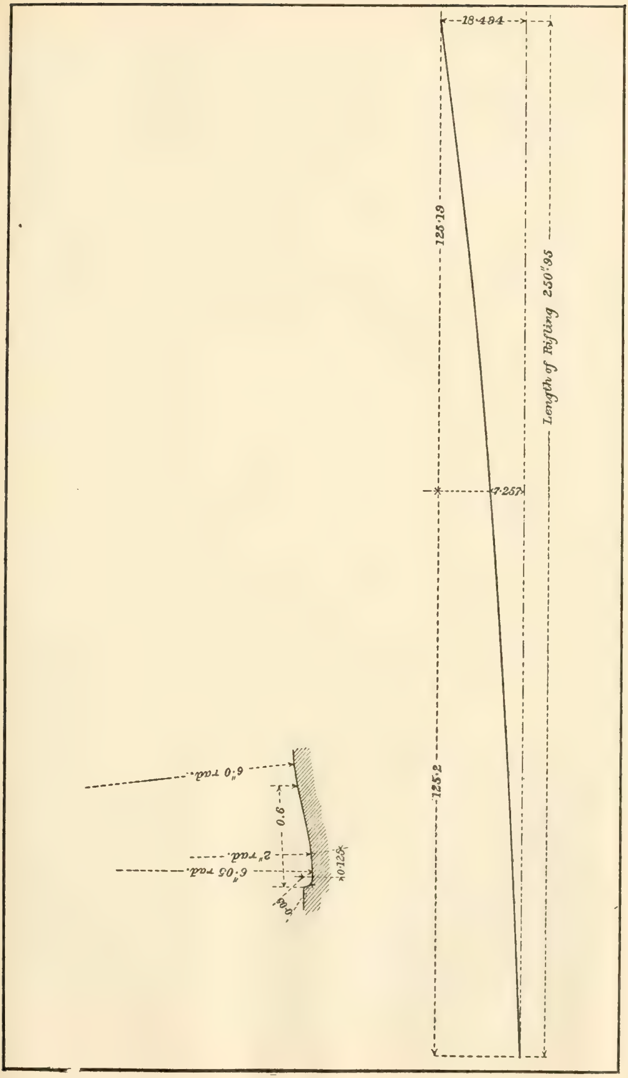
Experiments have produced results decidedly in favor of the Woolwich gun, and have fully warranted the conclusion, that large, short chambers are the most efficient.

"**Rifling.**—All the authorities, except Sir Joseph Whitworth, who adheres to the polygonal system, agree that the grooves should be numerous and shallow.

The rifling (Plate XXXVII.) is polygroove; the grooves are cut to a depth of 0.05 inch, and their non-driving edges are sloped to diminish the scoring. The twist is an increasing one (from about 1 in 120 calibers to about 1 in 35 calibers) for about half the length of the rifling; the other half, to the muzzle, being a uniform twist of about 1 in 35 calibers. The number of grooves is determined by the caliber and is the product of 4, and the diameter expressed in inches; thus, the 12-inch gun has 48.

Rotating Rings.—The Vavasseur rotating ring is now adopted by Woolwich and Elswick, the dimensions being determined by experiment. Mr. Vavasseur lays great stress on the position of the rotating ring on the projectile. He states

* Gun Foundry Board Report.



RIFLING OF 12-INCH 43-TON B. L. WOOLWICH GUN.

that it should be at the center of percussion with respect to the front bearing.

Wire Construction.—The employment of steel ribbon or wire in gun construction has been more or less considered since 1855, when Mr. James A. Longridge brought to the notice of the War Office his proposed method of increasing the strength of guns by this means. Some experiments were made, but they were not satisfactory. Of the strength that was given circumferentially there was no doubt, but the difficulties of providing it longitudinally were so great that the subject was dropped at the time. Recently, however, the matter has been taken up by Sir William Armstrong, who has manufactured several wire guns."*

In his presidential address to the Institution of Civil Engineers, he gave the following opinions :

But the problem is ever before us how to lessen the weight and increase the power of heavy ordnance, and we cannot rest satisfied with results, however good, if they be not the best that appear to be attainable. In saying this, I am led to speak of a system of construction which has not yet passed through the experimental stage, but which, from the results it has already given, promises to attain a wide application. I refer to that system in which the coils surrounding the central tube consist of steel wire, or ribbons of steel, wound spirally upon the tube. To those who object to welded coil tubes on the ground of supposed deficiency of longitudinal strength, this mode of construction must appear especially faulty, inasmuch as lateral adhesion, instead of being, as contended, merely deficient, is altogether absent ; while to those who advocate the present coil system this variety of it must commend itself as affording the greatest possible amount of circumferential strength that can be realized from the material employed. Steel in the form of wire or drawn ribbon possesses far greater tenacity, and also greater toughness, than in any other condition ; and in applying it to guns we have perfect command of the tension with which each layer is laid on. The idea of using wire for this purpose is far from new. It formed the subject of a patent obtained by Captain Blakely in February, 1855, and also of a patent taken by Mr. Longridge a few months later, soon after which time the late Mr. Brunel conceived the same idea, and, in ignorance of the existence of any patents on the subject, commissioned me to make for him a cannon upon this principle ; but as soon as he discovered that the ground was occupied by patents, he gave up the project, and for the same reason I abandoned it myself. Mr. Longridge has persistently advocated the use of wire for this purpose, and has more than once brought the subject before this Institution. He has also suggested a form of gun designed with a view of obviating the objection of want of longitudinal strength, but I am not

* Gun Foundry Board Report.

aware that his method of construction has been reduced to practice. Of the theoretical advantage of this system there can be no doubt, but the difficulties only begin when we endeavor to put the theory into practice, and no solution of the problem of how to do it can be accepted without the production and trial of an actual gun. My own attention was redirected to the subject nearly five years ago, when the patents had long expired ; and, after making various preliminary trials with small wired cylinders, a 6-inch breech-loading gun of this construction was commenced in 1879, and finished in the beginning of the following year, since which it has undergone many severe trials. The charges used with it were large beyond precedent, and the energies developed, proportionally high. Being satisfied with the results obtained with this gun, a second one of larger dimensions was commenced, and is now finished. Its caliber is 26 centimetres, or about 10¼ inches. Its length is 29 calibers, and its weight is 21 tons. In the previous gun I depended for end strength upon the thickness of barrel only, but in the new one layers of longitudinal ribbons are interposed between the coils in the proportion of one longitudinal layer to four circular layers. The longitudinals are secured to the trunnion-ring at one end, and to a breech-ring at the other, and are in themselves calculated as sufficient to resist the end strain on the breech, independently of the strength afforded by the tube. The whole is encased in hoops shrunk upon the exterior of the coil, for the treble purpose of protection from injury, of preventing slipping in the event of the failure of an external strand, and of adding to the strength of the gun. This gun has already been tried and given results, which, in relation to its weight, are unexampled except by its 6-inch predecessor. Various attempts have also been made abroad to reduce this system to practice, and it is understood that the French are at present engaged in making experimental guns upon the same general principle. With regard to the ribbon form of section, I prefer it to a square section of equal area, as being more favorable for bending over a cylinder ; but any rectangular form is better than round wire, on account of the flat bedding surfaces it affords.

Of Sir Wm. Armstrong's system of fabrication, his patents give the following description:

The wire is of rectangular section, and it is coiled upon the tube or cylinder between shoulders, one at either end. The wire is secured to the shoulders at the commencement and at the end of each layer. For this purpose radial grooves are cut in the shoulders. The wire before commencing to coil is headed at the end, and the head is inserted into one of the radial grooves corresponding in form with the head. To secure the end of the wire on the completion of the layer, the wire, as it lies upon the cylinder, is bent or bulged out so as to make it enter a groove (of another form) in the shoulder. The bending is effected by the insertion of a tapered tool between the last convolution of the wire and that which immediately precedes it. The groove in the shoulder is of such a form as to be filled by the bulge in the wire thus produced. Several tools may be employed in succession to force the wire home into the groove, and then a small filling piece is inserted into the cavity produced between the

two adjacent convolutions of the wire. Tapered filling pieces, passing around the cylinder, are laid against the shoulder, both at the commencement and the ending of the coiling of each layer of wire. These filling pieces occupy the spaces which would otherwise be left vacant between the coils and the shoulders. Over the coiled wire a jacketing tube, in one or several pieces, is applied, and is made to add to the longitudinal strength of the barrel through the intervention of a hoop fixed upon the breech end of the barrel beyond the base of the bore. This hoop may be notched or hooked upon the barrel in the usual manner where end hold is to be given ; and the jacketing cylinder may be similarly attached to the exterior circumference of the hoop, or the attachment may in both cases be effected by the method hereinafter described.

Where the necessary longitudinal strength cannot be obtained without making the barrel of objectionable thickness, I either make up the deficiency by shrinking upon the barrel an additional cylinder, above which the wire coils are applied, or I interpose between any two layers of spiral wire, or above or below them all, a layer or layers of longitudinal wires or rods, which are held against end strain by the friction due to the pressure of the superposed material in tension, and where the superposed material is deficient in thickness for that purpose, as it generally will be towards the ends of the cylinder to which the longitudinal wires are applied, I head the ends of the wires and notch them into a hoop firmly attached to the cylinder at each end of the coil.

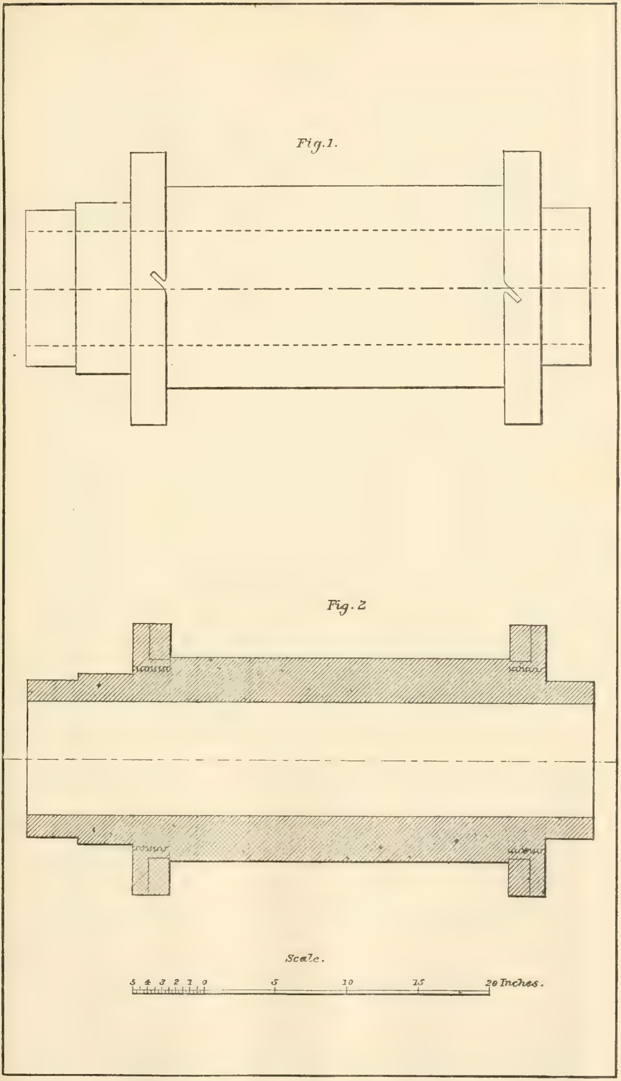
An additional advantage obtained by this arrangement is that the wire may be put on hot and allowed to contract so as to produce a state of initial tension, which increases their efficiency for longitudinal support. In order to obtain where needed a more effectual longitudinal connection between an enveloping cylinder and the barrel or cylinder it incloses than is afforded by the usual method of notching and hooking, I slightly reduce in diameter the end of the barrel or inclosed cylinder for a few inches in length, and screw the reduced surface. I also screw the enveloping cylinder for a similar length at the same end, so that when it is shrunk upon the barrel an annular cavity is left between the two screwed surfaces. Into this cavity I pour melted phosphor-bronze or other suitable metal, which is thus moulded into the form of an interlocking screw.

I also effect the same object by serrating the surfaces to be held against slipping and interposing a thin sheet of copper. The outer cylinder, being then shrunk upon the copper, squeezes the copper into the serrations and so interlocks the two cylinders.

Figure 1 (Plate XXXVIII.) represents a cylinder, and figure 2, a section of same, showing the arrangement of the cylinder and shoulder rings, between which the wire is circumferentially wound, and the recesses for securing the ends of the wire with plugs, figure 1, Plate XXXIX.

Figure 2 (Plate XXXIX.) shows in elevation and section the wire-ends secured by screws.

Figure 3 (Plate XL.) is a longitudinal section through an enveloping cylinder of coiled wire, A, containing four layers of longitudinal wires, each marked B; it also shows a similar section of a portion of a lower coiled wire cylinder, C,



CYLINDERS AS PREPARED BY ARMSTRONG TO RECEIVE WIRE.

Fig. 1.

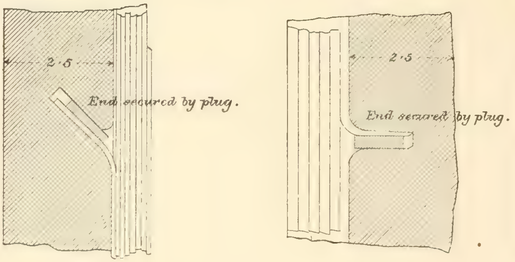
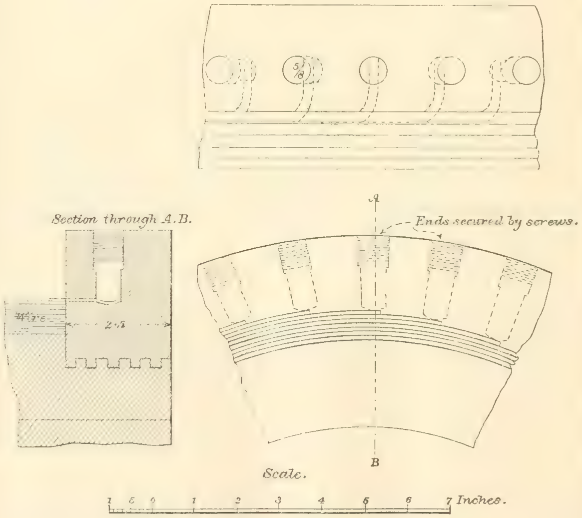
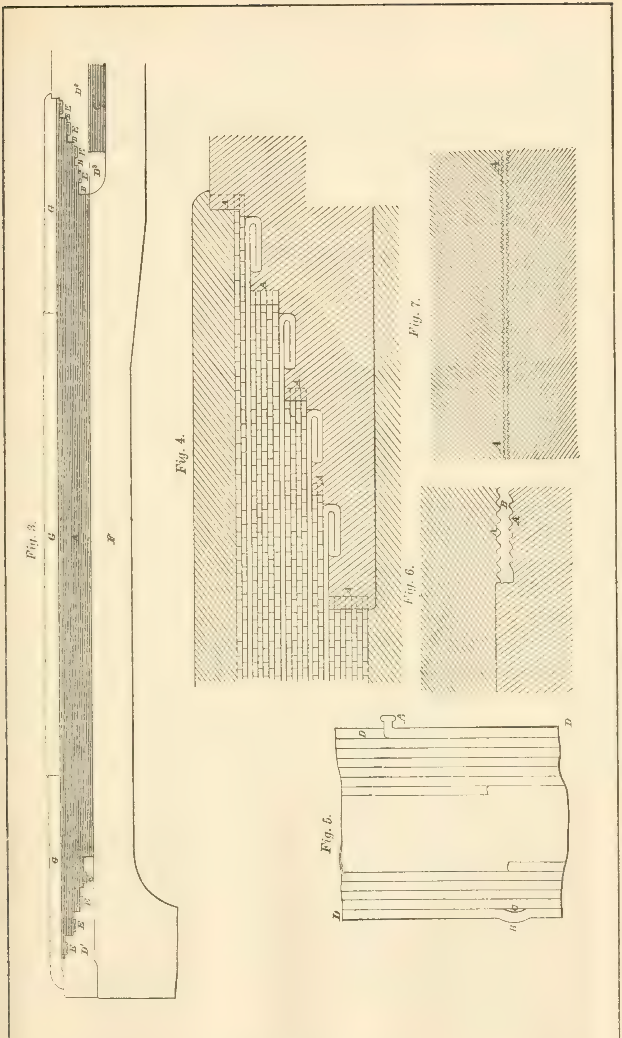


Fig. 2.



ARMSTRONG'S METHODS OF SECURING ENDS OF WIRE.



ARMSTRONG'S METHODS OF WINDING WIRE.

which does not contain any layers of longitudinal wires. D^1, D^2, and D^3 are the hoops to which the ends of the wires are made fast. The heads of the longitudinal wires and the circular grooves in which they are inserted are marked E. The cylinder on which the wire is coiled is shown at F, and the outer hoops or casing of the wire are marked G.

Figure 4 is an enlarged view of one end of figure 3, and shows each separate wire in section.

Figure 5 shows a side elevation or a plan of a portion of the tube or gun, and represents the mode of fastening the ends of the coiled wire. At the starting end of the coil the wire is formed into a gib of the shape shown at A, and is inserted into a radial groove of a corresponding form in the hoop to which the attachment is to be made. The depth of this radial groove may be sufficient to receive any number of wires. In figure 4 the depth of these grooves is shown by dotted vertical lines at the places marked A in that figure. The finishing end of the coil is fastened by bending the wire sideways, as shown at B, figure 5, into a radial groove of corresponding form. The bending is effected by a series of wedge-like tools inserted one after the other, and the end is finally secured by a wedge or filling piece, C. DD are inclined or tapered pieces laid in against the hoop to fill in between the coil and the hoop on the tube or gun.

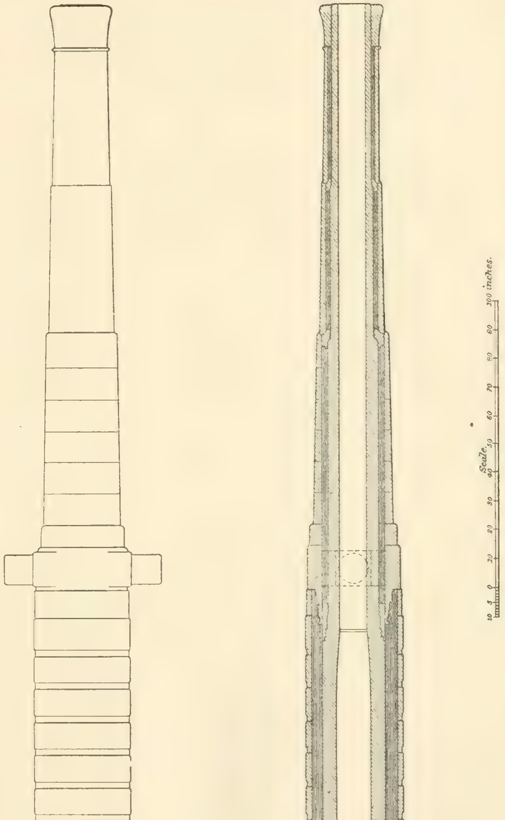
Figure 6 is a section showing the mode of fixing an outer cylinder upon an inner one so as to resist the tendency to slide longitudinally. AA are two grooved or screwed surfaces, the one on the outer and the other on the inner cylinder. Between these surfaces there is an annular space, B, to be filled with fused phosphor-bronze or other suitable metal. The fused metal becomes moulded into the grooves on either side and thus locks the two cylinders together.

Figure 7 is a section showing another modification of the method of preventing one cylinder sliding lengthways over another. In this case the surfaces of the cylinders are slightly serrated, as shown at AA, and a thin sheet of copper, or other compressible metal, is bent round the inner cylinder. The outer one is then shrunk upon the copper, which becomes imbedded in the serrations and so interlocks the surfaces. This method may be applied either at the ends of the cylinders, or at any intermediate part, or over the whole length.

"A 10.2-inch gun (Plate XLI.) of this manufacture has been purchased by the War Office and is now under trial. In this gun longitudinal strength is obtained by disposing some of the wire lengthwise around the tube, and some very satisfactory experiments have been made with it. The gun weighs 21 tons, is 25 calibers long, and the following present some of the particulars of the last reported firing:

Charge of powder	pounds...	220
Weight of projectile	do. ...	404
Muzzle velocity	feet.......	2160
Pressure per square inch	tons.......	17"*

* Gun Foundry Board Report.



10.2-INCH 21-TON ARMSTRONG WIRE B. L. R.

Colonel Crispin gave the following description of its assembling:

The steel tube constituting the body of the gun, after being turned to the dimensions, is provided with the different pieces affording shoulders, between which the forward sections of wire are wound or laid on. These rings being shrunk on, and having serrations corresponding to the ones on the tube, an intervening thin copper band, by its compression under shrinkage, locks them to the tube.

The rear band is also similarly attached to the tube. The tube, being then made ready for the reception of the wire, is properly centered in the coiling-lathe, and the different sections between the shoulders of the ring, except the rear section, have the ribbon steel applied, both circumferentially and under different tensions and longitudinally.

The trunnion-ring must be next shrunk on over the wire and part of the adjacent rings. The winding and laying on of the rear section of ribbon completes the wiring of the gun, at the breech twenty layers being placed around the body and four layers lengthwise of the bore. The different sections of wrought-iron hoops to complete the structure are laid on in succession and in turn, and the piece completed as far as the building up is concerned.

The approximate weight of the different parts are:

	TONS.
Tube (steel, Whitworth's fluid-compressed)........................	7.28
Steel ribbon..	5.93
Wrought-iron parts	7.79
Total..	21.00

"A 6-inch breech-loading gun and a 6.3-inch muzzle-loading howitzer manufactured by the same firm are also about to be tried. In these the longitudinal strength is entirely dependent on the steel tube. The same firm is manufacturing several 6-inch breech-loading guns in which the longitudinal strength is partially provided for by a jacket, the wire wrapping being only called upon to provide circumferential strength.

The Royal Gun Factory has taken up the subject and has matured designs for experiment on a large scale. In its designs the longitudinal strength is obtained by means of steel segmental hoops placed between layers of wire.

The following is the present state of the wire-gun question in England:

Manufacture of Sir William Armstrong:

Under trial, 10.2-inch breech-loading gun.

To be tried, 6-inch breech-loading gun, 6.3-inch muzzle-loading howitzer.

Manufacture of Royal Gun Factories :

Under manufacture, 10-inch breech-loading howitzer.

Recommended for manufacture, 15-inch breech-loading gun of 63 tons.

Opinions vary as to the form, size, and other characteristics of the wire. One authority recommends square wire for the first six or eight coils, gradually increasing the size of the wire as the coils proceed outwards. This authority states that the higher the elastic limit, the better, the breaking strain and the power of elongation being of comparatively small importance, and that the wire should never be strained up to its elastic limit. Another authority recommends a flat wire of 100 to 110 tons breaking strain wound on a tension of 60 tons for the inner, and about 70 tons for the outer, layers, the longitudinal strength to be provided by the inner tube of the gun and by steel segments divided longitudinally, but, when put together, forming a tube. Another authority states that the full benefit of wire cannot be obtained unless strained beyond its elastic limit. Another authority prefers wire of a circular section, being impossible to keep any other shape to gauge. For heavy guns he would use wire of 0.0984 section, with a breaking strain of about 125 tons, and an elongation of about 2 per cent. This authority says that the elastic limit of the wire should not be passed in winding it on. He estimates that there would be a saving in weight of about 30 per cent on the breech portion of the gun, and more certainty of manufacture than with steel hoops."*

The advantages claimed for the wire system of construction are :

1. That steel in small section can be obtained that possesses greater strength than is possible to get in any other form.

2. That each layer can be brought truly to its correct tension.

3. Flaws of manufacture can be easily detected, and if not discovered, are confined to that part in which they exist.

4. The parts of the gun are light and can be more certainly and easily produced and assembled.

5. For their manufacture, expensive and complicated plants are not needed.

On the other hand, however, increased length of guns, necessary for great range, and permitted by the acceptance of breech-loading

* Gun Foundry Board Report.

and the use of hydraulic carriages, requires a large steel-forging plant for the manufacture of the interior tube and for the jacket by which longitudinal strength is obtained. No system of longitudinal winding has yet been found satisfactory, and great difficulty is still experienced in providing a suitable machine for applying the wire.

Colonel Crispin, U. S. A., in his report of 1882 on "European Ordnance and Manufactures," has, in copies of letters-patent, described and given drawings of the apparatus employed by Sir Wm. Armstrong for that purpose. It has not proved adequate, and while the wire system of construction undoubtedly possesses great merit, it has not yet passed the experimental stage. The longitudinal strength must be provided for by the long steel jacket, and a perfect wire-winding machine is yet to be obtained.

III.

FRANCE.

Sources of Supply and Condition of Artillery.

In France, as in England, the most friendly welcomes were tendered the Board at all the Government and private establishments it expressed a desire to visit, and everything was done, that courtesy and attention could devise, to assist the Board in its investigations.

"SOURCES FROM WHICH THE ARMAMENT OF FRANCE IS SUPPLIED.

Previous to the Franco-German war of 1870, it was the custom in France to confide all matters relating to cannon to the artillery corps of the army and navy; aid from private sources was neither sought nor offered; much secrecy was observed in all things relating to the business of ordnance; admission to the Government foundries was obtained with difficulty, and the experimental ground at Gâvre, with rare exceptions, was closed to all applicants.

For army purposes, the gun factories at Bourges, Puteaux, and Tarbes supplied all demands, while for the use of the navy the foundries of Ruelle and of Nevers, and the gun factories attached to them, provided the entire armaments.

With the advent of the war came the proof that a close corporation, such as was constituted by the system heretofore adopted, could not work to the best advantage of the country; and, with the return of peace and the necessity of re-armament, came a revolution of ideas which has led the Government to modify its practice.

It was recognized that the Government must have under its control some establishments purely governmental; but that, in order to provide for all contingencies as well as to prevent official ideas from running too much in a groove, it was desirable to encourage private industries, so that a spirit of emula-

tion might be excited by competition and a channel afforded through which new ideas and inventions might reach the national works. The adoption of this course was made the more imperative in consequence of the new departure in gun-metal, and this opened the way to the encouragement of the steel industries of the country.

The plan thus decided on has been consistently carried out. The Government gave assurances to the private companies, which induced them to expend the funds necessary to erect new and suitable tools, both for the casting of the metal and the fabrication of the guns.

The result of this action can be appreciated by reference to the following list of private companies which are now employed in providing armaments for the Government:

STEEL MANUFACTORIES PRODUCING STEEL UP TO TUBES FOR 16-CENTIMETRE GUN.

Jacob Holza & Co..Unieux (Loire).
Marrel Frères..Rive de Gier (Loire).
Société des Aciéries et Forges de Firminy..........Firminy (Loire).
Compagnie des Forges et Aciéries de St. Étienne, St. Étienne.

STEEL MANUFACTORIES PRODUCING STEEL UP TO TUBES FOR 42-CENTIMETRE GUN.

Henri Schneider & Co..Le Creusot.
Aciérie de la Marine..St. Chamond.

PRIVATE COMPANIES HAVING PLANT OF GUN FACTORY.

Henri Schneider..Le Creusot.
Cail & Co..Paris.
Société des Forges et Chantiers de la Méditerrannée, Havre.
Compagnie de Fives-Lille..Fives-Lille (Nord).
Société Anonyme de Constructions Navales de Havre..Havre.
Aciérie de la Marine..St. Chamond.

STEEL MANUFACTORIES PRODUCING ARMOR-PLATES.

Henri Schneider & Co. (forged steel)..................Le Creusot.
Aciérie de la Marine (compound)..........................St. Chamond.
Marrel Frères (compound)..........................Rive de Gier.
Chatillon et Commentry (compound)..........................Montluçon.

The compound plates are manufactured under the patent of Mr. Wilson, of Charles Cammell & Co., Sheffield, England.

All the gun-carriages for the navy and for coast defence are made at private works.

The above lists illustrate the immense increase of resources that the Government has obtained by encouraging private industries, and they contribute an important historical chapter for the instruction of a government about to provide an armament for its military services.

The following is the list of the government works manufacturing for the army, viz.:

(1.) Fonderie de Canons à Bourges, in the center of France. At this place, steel guns are made of 90 millimetres, 155 millimetres, 190 millimetres, and 240 millimetres; also, rifled mortars of 220 millimetres.

(2.) Atelier de Construction à Tarbes, in the Hautes Pyrenées, in the southwest part of France. At this place, steel guns are made of 90 millimetres, and 120 millimetres; also, carriages for field and siege guns.

(3.) Atelier de Construction de Puteaux, near Paris. At this place, all the steel mountain and field guns of 80 millimetres are made; also siege guns of 120 millimetres, and the Hotchkiss revolving cannon for flank defence.

(4.) Gun carriages, limbers, &c., are made at government shops at Vernon, Avignon, and at Angers.

Gun-carriages are also manufactured for the army at private works.

Bourges.—The gun factories of the army fabricate no guns above the caliber of 24 centimetres, and it is only at Bourges that army guns of this caliber are constructed. At the private establishments mentioned above, the work of fabrication has been carried as high as 34 centimetres, but the advantageous working capacity of the factories does not extend beyond the 24-centimetre gun."*

The Artillery Establishment at Bourges comprises foundry, gun shops, laboratory, testing rooms, and proving-ground. All are well equipped, and the shops are well placed and lighted. The steam-hammer has a tup of 4 tons.

The parts of the guns are received from Le Creusot, St. Chamond, and St. Étienne, rough bored, turned, and tempered, and are machined and assembled here. 1300 men are actively employed.

The pump of the Maillard testing-machine is driven by a small

* Gun Foundry Board Report.

Gramme electric-motor, which furnishes light at night. Of the electric-travelling crane, Lieut.-Colonel Abbot, U. S. A., in his "Hasty Notes relating to Military Engineering in Europe," has given the following description :

In one of the shops at the army gun factory at Bourges, France, we saw a very interesting application of electricity which may perhaps find a place upon some of our special works of construction in the future.

This shop is about 300 feet from another building which contains an immense engine driving many different machines, and therefore necessarily possessing considerable surplus power. It was considered that through the agency of electricity some of this might be made available in the first-named building, for performing the intermittent kind of work required of a large crane. The engine was accordingly connected permanently with the armature of a large Gramme machine, the work of revolving this armature being practically *nil* except when the external circuit is closed.

This external circuit was carried to the building in question by two large copper conducting wires, which were conveniently led overhead in such a manner as to supply a rubbing contact at all desired parts of the shop.

The crane was of the usual overhead pattern, travelling longitudinally on rails running over the bays containing the tools to be served. Convenient cross tracks were arranged for shunting its carriage from one bay to another, so that one single crane could perform work in any part of the building. Its lifting power was about 20 tons. Contact brushes on the carriage rubbed the wires, and thus extended the circuit down to a second Gramme machine suspended from the carriage at a convenient level near the floor. When a permanent break in the circuit near this machine was closed by the operator, the current traversed the second Gramme, which thus became a motor, its armature revolving by the power of the distant engine transmitted through the agency of the current.

I estimated the size of this motor armature at 12 inches in diameter by 18 inches long. Each end of its axis was extended beyond the field magnets to carry a leather-wrapped pulley, about 18 inches in diameter. They rubbed iron pulleys about 30 inches in diameter, which were connected to trains of gearing so arranged as to move the carriage on the tracks, or to shift the crane laterally on the carriage, or to raise and lower the suspended weight, as desired.

The following electrical data were furnished by the officer in charge. The armature of the generating machine revolves about 1000 times per minute ; and that of the motor from 600 to 1000 times. The electromotive force is about 400 volts and the current about 35 ampères. The system can transmit the power of about 12 horses with an economic return of $\frac{60}{100}$. The cost of the crane was about $7000. It was made by Bon et Lustremont, 25 Rue Poissonnière, Boulevard Poissonnière, Paris. It was favorably regarded, its working being economical and convenient under the special circumstances of the case.

Ruelle.—The foundry at Ruelle, near Angoulême, has become the principal if not the only establishment for the manufacture of the

larger calibers designed for the navy and coast. That at Nevers is no longer used, most of its machinery having been transferred to Ruelle.

Three circumstances contributed to the creation of Ruelle and the appropriation to its present purposes: First, the hydraulic power that is continually supplied by the river Touvre, whose waters neither dry up, overflow, nor freeze. Second, the proximity of special ores producing iron that possesses extreme resistance to the action of powder. Third, the not less useful neighborhood of forests that furnish in abundance the only fuel, charcoal, considered at that time admissible for metallurgy.

Whatever its origin, the river that provides Ruelle with its motive power has a force varying from 130 to 420 horse-power, according to the season. Before reaching the foundry, it contributes power to several paper-mills. Below the last one is a large dam, which divides the river into two branches, one, the discharge, passing around the works. Nine flood-gates, raised and lowered by means of racks and pinions, govern the volume of water that feeds the shops.

About the middle of the 18th century, the Marquis of Montalembert bought a paper-mill for a perpetual annual rental of £365. Upon this site he built a foundry for cast-iron. Authorized by patents of 1751, he obtained in 1752 a decree that allowed him to cut, for nine years, in the Bracoune forest, northeast of Ruelle, 4000 acres of wood.

In 1755, in the summary manner of the time, the Government seized the foundry, and for sixteen years the Marquis could not recover his property. In 1772, his proprietorship was admitted, but he was ordered to lease the works to the Government for a rental of £20,000 per year and a bonus. Two years later, Count d'Artois bought the foundries of Ruelle and Forge-Neuve for £300,000, the equipment and tools being valued at £60,000. In 1776, the King took them from Count d'Artois and gave him in exchange three forests in Champagne. The foundry was administered by a Board of Directors, afterwards by contractors. The fabrication at that time was very simple. The fuel was charcoal from the Bracoune forests. The cannon were cast in earthen moulds, sometimes with a core, and often solid. The boring-machines were the invention of the Marquis of Montalembert.

But the time soon came when France was threatened by the navies of all Europe. Six thousand cannon were needed immediately, and the Committee of Public Safety proceeded to take measures to meet this demand. It divided into four departments the smelting furnaces and forges that could be utilized, and substituted for earth-moulds the

more rapid sand process. Models of machines and tools were sent to the foundries, intelligent workmen were employed, and the experts Perrier, Haasenfratz, and Mouze published works upon the art of fabricating cannon. Ruelle was entirely renewed; other foundries were added, two reverberating furnaces were introduced, and new boring-machines replaced the former tools.

In 1803, the system was changed, and Ruelle absorbed the other departments. In 1823, reverberating furnaces were erected, which exist to-day. In 1840, the bronze foundry and the boring-shop at Rochefort were transferred to Ruelle, and in 1846 a chemical laboratory was added. From this date until the present time the modifications have been continual. While complete arrangements of furnaces, moulds and flasks for hollow and solid casting, appliances for internal cooling, and the ordinary implements for shrinking and assembling are still retained, to-day almost the entire establishment is under reconstruction to keep pace with the progress of manufacture and to meet the increasing demands for heavy steel cannon. The plant is scattered and consequently difficult and expensive to superintend; but with the completion of the two new shops, this objection will be met. And while the hydraulic motive power is still excellent, steam will be employed.

> "At the 'Fonderie à Ruelle' all the constructive force of the marine artillery has been concentrated, and here all the largest guns are made. It contains the most remarkable collection of tools of the age. They are designed for guns of 34 centimetres and upwards, and have a capacity for handling guns of 160 tons in weight and 60 feet in length. The shop in which these tools are placed is about 450 feet in length and 131 feet in width, having a height of 85 feet at the central peak of the roof. At one end is the tubage* pit, in which the gun tube is placed upright to receive the hoops. The bottom of this pit is at a depth of 85 feet below the floor. It is excavated in a rectangular form and is divided into four stories, contracting in area as the lower level is reached; at each story or landing place, the opening can be floored over to accommodate the work of hooping any length of tube. The heating furnaces are on the first story below the floor. The tools already in place are the following, but there is room for fully a dozen more of similar character:

* Shrinking.

Two turning lathes, capable of turning guns 15 metres long. These can be increased in length 10 metres.

Three boring machines for same.

One rifling machine for same.

Two smaller boring machines with adjustable connections for turning.

Two other machines for performing all the details of the work about the breech, for receiving the fermeture, turning the screw, slotting, piercing holes, &c.

Two movable cranes ; one of 100 tons, the other of 30 tons capacity.

The contractors for these tools were Varall, Elwell & Middleton, Paris. The plant has cost millions of francs, and five years elapsed from the giving of the order to the setting up of the tools. A large portion of the time charged to the manufacture must be credited to the preparation of designs, no tools of their size and great capacity having been before conceived."*

The 100-ton hydraulic crane (Plate XLII.), for the transfer of heavy guns to barges, was constructed at Fives-Lille in 1882, at which place the railway truck in use here was also made. The latter has a capacity of 120 tons, and is similar in construction to that (page 723) manufactured by Schneider and Company at Le Creusot.

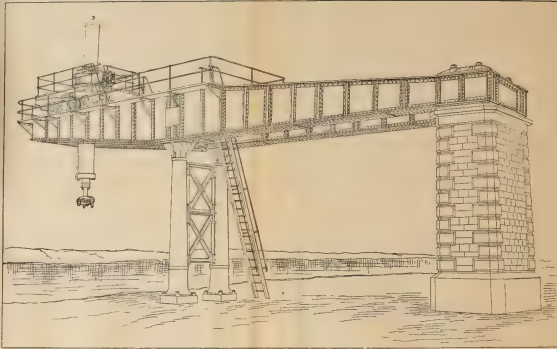
"Taking the above notice of the works at Ruelle in connection with what has been stated on the subject of private industries, it will be seen how well all the requirements are provided for a joint production of cannon by the Government and private parties. The latter assist up to a point justifying on their part a reasonable outlay of money for a plant, and the Government, though working in this common field as well, yet reserves to itself all the more onerous charges involved in the manufacture of the heaviest ordnance.

It seems as if in France the happy mean has been reached by which the Government and the private industries can work harmoniously towards the accomplishment of a national object.

In a combined system of this kind, it is very important to be assured that there exist mutual checks which act to prevent the one party imposing improper or hard terms on the other. The board is not without evidence of the existence of these salutary checks in France.

A short time since, the Government deemed it necessary to increase its armament by 300 additional guns, and decided

* Gun Foundry Board Report.



100-TON HYDRAULIC CRANE NEAR RUELLE.

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* Gun Foundry Board Report.

that certain additional tests should be required of the metal for the tubes. When the provisions of the proposed contract were made known to the steel manufacturers, they resisted the requirements as being too hard, and insisted on the acceptance of such steel as had been previously supplied; but to this the Government would not accede. Finding them determined in their resistance, the Government made inquiries abroad as to the possibility of securing the metal it required, and, finding that a foreign manufacturer would undertake the contract, a promise was given to him that he should receive the order. The steel manufacturers of France, hearing that the order was likely to be given to a foreign firm, endeavored to arouse a national feeling on the subject to constrain the Government to make the purchase in France, but to no effect; and they finally proposed to accept the government proposition. But the minister had already given his word to the foreign manufacturer and the contract was lost to France. In this instance, both parties, the Government and the private companies, acted within their independent rights, but neither could compel the other. This exhibition of effective counterpoise is a good proof of a happy adjustment of forces.

CONDITION OF STEEL MANUFACTURE.

Since the termination of the Franco-German war of 1870, and in the course of the re-armament of the country, the Government has given every encouragement to private industries to justify them in incurring the expense of establishing plants at various points to assist in the construction of guns; and by embarking largely in the fabrication of *steel* cannon it has given a great impetus to the manufacture of this important material. The numerous works that can produce metal suitable for tubes and hoops for field-pieces have been mentioned. These establishments have made a study of the subject of gun-metal, and, so far as their facilities for forging reach, can all supply the demands that the country can make upon them."*

Works of Marrell Brothers.—Besides the manufacture of compound armor plates at Couzon (a few minutes' rail ride from Rive-de-Gier), under the Wilson patents and with Siemens furnaces, the steel works

* Gun Foundry Board Report.

of Marrell Brothers at Rive-de-Gier are well equipped for the manufacture of steel shafting, large machinery, and gun tubes up to 17 centimetres caliber. There are four steam-hammers with tups of from 10 to 25 tons; all are double-acting and have a stroke of 8 feet. The gun-tubes are of open-hearth steel, tempered in oil; after tempering, they are bored to the close dimensions required by the French contracts, in many instances to $\frac{3}{1000}$ of a millimetre of the finished size.

> " For tubes and hoops, however, for large guns, requiring massive forgings, the supply is limited to the works of the 'Compagnie de l'Aciérie de la Marine' at St. Chamond, and to those of H. Schneider & Co., at Le Creusot, the former having a steam-hammer of 80 tons, and the latter, one of 100 tons weight.
>
> There are some establishments, notably at St. Étienne, where crucible steel of a high order is manufactured for purposes of trade, but no effort is made to utilize it for gun purposes."*

St. Chamond.—At this immense establishment, called "La Compagnie des Hauts–Fourneaux, Forges et Aciérie de la Marine et des Chemins de fer à St. Chamond," with its capital of twenty millions of francs, the shops are very extensive, and contain excellent tools. Some very fine turning-lathes in use were manufactured by Jouffrey at Vienne, France. The forge contains three large hammers of 10, 35, and 80-ton tups. The largest was constructed at the works at a cost variously estimated from one to two millions of francs; it is double-acting, with a stroke of 18 feet; steam is not used above. The foundation is rock covered with wood and 800 tons of iron castings, the largest of which weighed 130 tons.

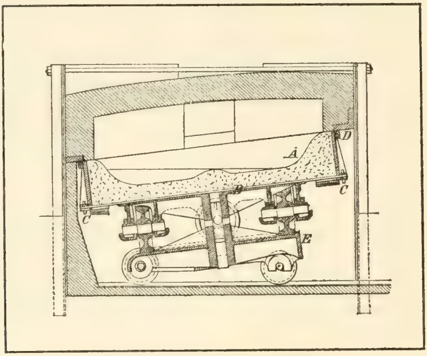
> " The cast steel used for cannon in France is manufactured by the Open-Hearth process with Siemens furnaces. This process is combined with the rotating-hearth of M. Pernot at St. Chamond, where three 25-ton and two 12-ton Pernot furnaces give a capacity for casting an ingot of 100 tons."*

M. Pernot, who has charge of them, rendered the operation of puddling very much easier by the invention of his rotary furnace.

Lieutenant Chase has described it as

Composed of a stationary part comprising the fire-place, the laboratory chamber, and the flue, and the movable part comprising the laboratory A, page 692, and its support E.

* Gun Foundry Board Report.



PERNOT ROTARY HEARTH.

The laboratory is a circular tub A, the bottom of which is a stout iron plate B, and the walls, segments of cast-iron. These are joined to the bottom by bolts and keys C, and stiffened at the top by an iron band D. Below the bottom of the tub is fixed a slightly conical cogged cap, by the aid of which the laboratory may be given a rotary motion around an axis inclined 6 or 7 degrees from the vertical.

The sole is formed as usual, but is spread to a greater height against the walls and at the center of the tub, to give an annular form to the bottom of the laboratory.

Between the walls of the movable tub and its roof, there is a joint, the thickness of which, reduced as much as possible, sometimes reaches fifteen inches, in consequence of movements which cannot be prevented in masses heated as much as the walls of a puddling furnace. This joint enforces the employment of a blast to feed the grate.

The rotation of the laboratory, without completely doing away with the rabbling, renders it less laborious. It effects it so long as the charge is liquid; but when it becomes pasty, and as the velocity of rotation, which does not exceed three revolutions per minute, is not sufficient by itself to insure proper stirring, the movement of the oven contributes very much to diminish the labor of the workman, who has only to place his puddling-bar on the bottom and rest it against the side of the working door. In this way all parts of the bath come in contact with the bar, and the rotation replaces the rapid movements to and fro which the puddler must give his bar in the ordinary furnace.

Besides the relief to the puddler, the production is largely increased by the aid of additional furnace chariots, which can be run out and prepared while the others are in use.

The works have a capacity for making the heaviest products that the period will probably demand.

> "The ingots cast here for the 42-centimetre 75-ton guns are of 75 tons weight; the tube, after rough-boring and turning, weighs about 35 tons.
>
> The tempering-pit is a large excavation 15 metres deep. At one extremity is the furnace where the tube is placed erect and heated. At the other is a cylindrical excavation, reaching to 15 metres below the floor of the pit, where is placed the tank containing 100 tons of colza oil into which the tube when heated is lowered rapidly.
>
> **Le Creusot.**—The most important steel works in France are situated at Le Creusot and bear the name of the location in which they are situated. These works have advanced year by year in importance and in magnitude since their purchase by Mr. Eugene Schneider.
>
> This gentleman's death, in 1875, was a source of mourning to the whole town, the inhabitants of which looked up to him as a father. The grateful people have erected to his memory a monument in the market square.
>
> Under the administration of his son, Mr. Henry Schneider, the fame of the products of the works has been enhanced, and the proportions of the establishment have been much increased. The whole number of workmen now employed here and at other points amounts to 15,000; and it is the great center of industry of the adjoining region. At no other place in the world is steel handled in such masses, and it is safe to say that no proposed work can be of such magnitude as to exceed the resources of the establishment."*

It comprises (Plate XLIII.), coal mines, smelting furnaces, foundries, forges, steel works, and construction shops. It is the chief city in the district of Autun, and is 400 kilometres south-east of Paris. Advantageously situated in the center of France, at an altitude of 380 metres, closely connected by rail with the Burgundy and Bourbon districts, united by a private railway to the Central Canal, which is about 10 kilometres distant, and which gives easy access to the Loire, Saône, and Rhône,—Le Creusot, by its rail and water ways, is in communication with the sea and the Mediterranean, and with all parts of France.

* Gun Foundry Board Report.


CHNEIDER AND COMPANY
PLAN
WORKS OF LE CREUSOT,
FRANCE.
1878.
N
Coal Pits
General Shops
Steel Works
Construction Shops
Blast Furnaces
Mixed Railway
Forge
Works
Park

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This gentleman's death, in 1875, was a source of mourning to the whole town, the inhabitants of which looked up to him as a father. The grateful people have erected to his memory a monument in the market square.

Under the administration of his son, Mr. Henry Schneider, the fame of the products of the works has been enhanced, and the proportions of the establishment have been much increased. The whole number of workmen now employed here and at other points amounts to 15,000; and it is the great center of industry of the adjoining region. At no other place in the world is steel handled in such masses, and it is safe to say that no proposed work can be of such magnitude as to exceed the resources of the establishment."*

It comprises (Plate XLIII.), coal mines, smelting furnaces, foundries, forges, steel works, and construction shops. It is the chief city in the district of Autun, and is 400 kilometres south-east of Paris. Advantageously situated in the center of France, at an altitude of 380 metres, closely connected by rail with the Burgundy and Bourbon districts, united by a private railway to the Central Canal, which is about 10 kilometres distant, and which gives easy access to the Loire, Saône, and Rhône,—Le Creusot, by its rail and water ways, is in communication with the sea and the Mediterranean, and with all parts of France.

* Gun Foundry Board Report.

Its history dates from 1782, when, under the name *La Charbonnière*, its industry was the extraction of coal. Under the patronage of Louis XVI., a cannon foundry was established, which was successful for several years. In 1784, Queen Marie Antoinette founded a crystal manufactory, which continued in operation until 1832. During the revolution of 1815, cannon and projectiles were cast at Le Creusot. Successive reverses marked the first period of the existence of the establishment. In 1818, the Messrs. Chagot bought it for 900,000 francs, but were forced to cede it, in 1826, to the Manby-Wilson Company, who bought five-sixteenths of the property for a million francs. They made extensive changes, which caused their failure in 1833, and the property returned to Messrs. Chagot and others. Finally, in 1836 it was sold to Messrs. Schneider Brothers and Company for 2,680,000 francs. From this epoch dates the prosperity that has made the works the finest establishment of its kind in the world.

The first locomotive built in France was made at Le Creusot in 1838, and from 1839 to 1842, in addition to locomotives for the railways from St. Germain to Versailles, and from Saint-Étienne to Roanne, Messrs. Schneider furnished steamboats for the Saône and Rhône. In 1842, M. Bourdon, chief engineer of the works, commenced the construction of the first steam-hammer in France, and its completion added a new and most important factor to the already well-equipped forge.

In 1845, M. Adolphe Schneider was thrown from his horse and killed. Mr. Eugene Schneider was thus left sole head, and the firm's name was changed to Schneider and Company.

In 1855, during the war of the Crimea, great demands were made of Creusot, but they were so well met that in seven months there were furnished 17 engines of 150 horse-power for gunboats and floating batteries; 4 engines of 650 horse-power for ships-of-the-line; and 4 engines of 800 horse-power for frigates were commenced. From 1856 to 1862, immense additions were made, and though the commercial treaties of 1860 opened all the French ports to foreign competition and the situation was critical, the *forge* was entirely reconstructed on a new site, and the railways were extended. A large *brick-yard* was also established at Perreuil, on the banks of the Canal. The number of smelting furnaces was increased. The different departments were connected by telegraph, which greatly facilitated the work.

In 1867, Le Creusot presented to the public the first methodical and rational classification of cast and wrought-iron in qualities suitable

for all purposes. About this time the steel industry appeared, and the Siemens-Martin process was introduced. The Bessemer soon followed, accompanied by the fabrication of steel rails and soft steel for the construction of ships, as well as material for cannon. Creusot has contributed largely to the development and improvement of gun steel. In 1873, the fabrication of steel tires was undertaken; and, for the manufacture of shafts for large marine engines and of the parts of guns of enormous weight, the 80-ton hammer was erected in 1876 and completed in 1877. With this hammer were forged the armor plates that were so successful at Spezia, and in 1878, plates weighing 65 tons, and cast ingots of 120 tons were produced at this wonderful establishment. The acquisition of the Pernot rotary-furnace has increased the open-hearth products and reduced the labor of the puddler; and the introduction of the Basic process has enabled them to utilize any inferior ores that their mines discharged. The offices and principal workshops are lighted by electricity, permitting the operations to be as easily performed at night as by day.

Under the administration of Messrs. Schneider and Company, besides the immense establishment proper at Le Creusot (Plate XLIII.), we find to-day the following annexes:

Ship-yard and bridge construction shops at Chalon-sur-Saône (Saône-et-Loire).

Brick-yard at Perreuil (Saône-et-Loire).

Coal mines of Montchanin and Longpendu (Saône-et-Loire).

Coal mines of Decize (Nièvre).

Coal mines of Montaud (Loire).

Coal mines of Beaubrun (Loire).

Coal mines of Brassoc (Puy-de-Dôme).

Iron mines of Mazenay (Saône-et-Loire).

Iron mines of Allevard (Isère).

Iron mines of Savoie (Savoie).

This vast installation covers 2857 acres, 1048 of which are actually occupied by buildings and works of various descriptions. The effective working force comprises 15,500 men, distributed as follows in the different departments:

Iron mines,	2,000	Forges,	2,700
Coal mines,	5,000	Construction shops,	2,800
Smelting furnaces,	700	Railway and other services,	1,500
Steel works,	800		
Total,			15,500

In 1880–1881, to meet the production, there were consumed:

621,000 tons of coal,
200,000 tons of coke,
517,000 tons of ore,
3,600,000 cubic metres of water,
2,800,000 cubic metres of gas.

The working capacity of the establishment was:

700,000 tons of coal,
200,000 tons of pig iron,
160,000 tons of wrought-iron and steel,
30,000 tons of constructed material,

represented by metallic bridges, river steamers, marine and stationary engines, locomotives, iron and steel rails, wrought-iron and steel for all regular commercial purposes, armor-plates, cannon, and gun-carriages.

There are thirteen *smelting furnaces* (Plate XLIII.), several covered with brick; but the more recently constructed have metallic covers of the Scotch type. They are conveniently fed from a platform 38 feet high and 550 yards long. The powerful blowing engines are arranged in three groups: The first comprises three horizontal engines of high speed; the second, four vertical direct-acting engines of 200 horse-power each; the third, two vertical engines of 250 horse-power each, with the air-cylinder above the steam. The draft is produced by two chimneys, one of brick, 246 feet high, the other of iron, 278 feet high.

The coke employed for fuel is all made at the works from bituminous coal, found in the basin of the Loire, mixed with the anthracite of Creusot. The crushing machines are of the system Bérard and Carr. The carbonization is effected in 190 Belgian and 13 Appolt ovens of 18 compartments each, and the daily production is about 520 tons of a very dense and glutinous coke. It contains very little sulphur, which explains, in part, the excellence of the Creusot irons.

The *steel works* (Plate XLIII.) are represented by three groups of Bessemer converters, seven Siemens furnaces, and two Pernot rotary-furnaces. The cranes and engines of the Bessemer plant are actuated by hydraulic power under an accumulated pressure of 20 atmospheres, maintained by two engines of 40 horse-power each. Two engines, developing 2000 horse-power, provide the blast.

> "The capacity for casting steel is represented by seven open-hearth furnaces of 18 tons each, equal to 126 tons; and the process of casting large ingots is a model of order and security.

Ladles capable of holding the contents of one furnace, mounted upon platform cars, are successively filled at a previously determined interval of time and run on railways to a convenient position over the mould; before the first ladle is exhausted, the supply from the succeeding one has commenced to run, and so on to the completion of the casting, the supply to the mould being uninterrupted during the entire process. The precision with which the several ladles are brought into position in succession makes it entirely unnecessary to provide a common reservoir into which all the furnaces may discharge. By this process, the casting of a 45-ton ingot, which was witnessed by the Board, was effected in 23 minutes.

Perhaps the most striking feature at Le Creusot is the forge (Plate XLIV.), where is assembled an array of steam-hammers not equalled in the world, viz.:

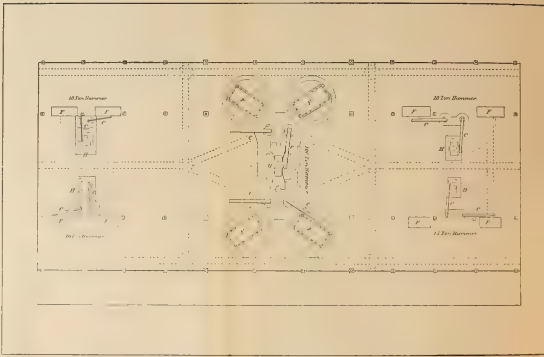
One 100-ton hammer with a fall of 5 metres.
One 40-ton hammer with a fall of 3 metres.
One 15-ton hammer with a fall of 3 metres.
Two 10-ton hammers with a fall of 2½ metres.
One 8-ton hammer with a fall of 2½ metres." *

As before stated, this great forge was commenced in 1862, when it was found that the one in use, although very large, was not equal to the demand.

The new buildings (Plate XLIII.) are situated near the steel works, and cover a surface of 30 acres. They extend over a distance of more than 550 yards, and comprise steam and hand forges, with their accessories, puddling furnaces, a central court for a convenient arrangement of railway communication, and huge rolls that shape the heated ingots into any required forms.

The bays that contain these rolls are 330 yards long and 100 yards wide. On the right is placed a long file of reverberatory furnaces. In the center there are 20 rolls run by 15 engines of over 6000 horse-power. The fly-wheel of one of these engines is 33 feet in diameter and weighs nearly 60 tons. The enormous quantity of steam required for these shops is furnished by vertical boilers, and is generated by the surplus heat from the reverberating furnaces. The reservoir that feeds them and further supplies the forge, has a capacity of 300,000 cubic metres.

* Gun Foundry Board Report.



PLAN OF HEAVY STEAM FORGING PLANT, LE CREUSOT

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* Gun Foundry Board Report.

Tire-rolling and bending-machines are suitably placed for the work required of them.

The roof of these buildings is metallic, but no trouble has ensued from the contraction and expansion, as predicted by some.

In addition to the installation of steam-hammers, represented in Plate XLIII., in the bays on each side of the central building there are other smaller ones. Plate XLIV. shows the plan accepted by the Messrs. Schneider for their heavy steam-forging plant. HH are the hammers, FF the furnaces, and CC the cranes. It has proved a most convenient system.

The following description of the 80-ton hammer and its accessories, furnished by Mr. Schneider, and translated from the "Annales Industrielles" of Paris, was published in the London "*Engineer*," of May 10, 1878:

Messrs. Schneider & Co. have recently erected a hammer, nominally of 80 tons, but one, the power of which is hardly measured by that weight. Messrs. Schneider commenced to design a hammer of 60 tons; but the evident future requirements of greater power caused them to decide in favor of increasing it to 80 tons.

The hammer is not alone to be considered; for its service, furnaces are necessary to heat the immense pieces, to manipulate which, cranes and wagons are required, to say nothing of the innumerable appliances also rendered necessary, and all of which render the establishment of such a plant one of serious difficulty and cost. The largest hammer hitherto at Creusot was 28 tons, and in leaping to the construction of one of 80 tons, they met with difficulties not encountered at Essen, Perm, or Woolwich. The work of a hammer depends on the value of impact force, which is difficult of exact measurement, but may be sufficiently approximated to enable one to proceed from, say, the construction of a 30-ton hammer to one of 50 tons, that is, from the known to the unknown, with a sufficient amount of certainty; but this can hardly be said with reference to a leap to 80 tons. The difficulties attending these operations have, however, been overcome by Messrs. Schneider.

The *building*, which is entirely metallic, is a prolongation of the large forge or smithy in which the largest forgings have hitherto been made. In the near future it is intended to extend this building in order that the high part now erected may stand in the center between two large shops of less altitude, and thus the architectural balance will be restored to the elevation. The new building is 50m. in length, 35m. in width, and 17m. under the foot of the rafters. A foot-bridge supported on the girders forming the rising-pieces serves to support two 20-ton crabs, which command the hammer for repairs. The 80-ton hammer occupies the center of the building (Plate XLIV.), and is served by four splendid cranes C, one placed near each corner, one capable of lifting 160 tons, and the others, each 100 tons. The four furnaces F are

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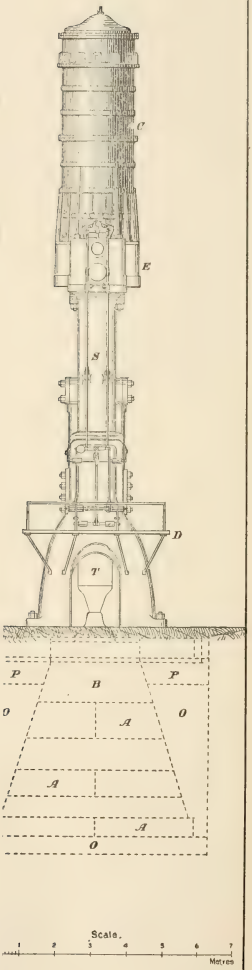
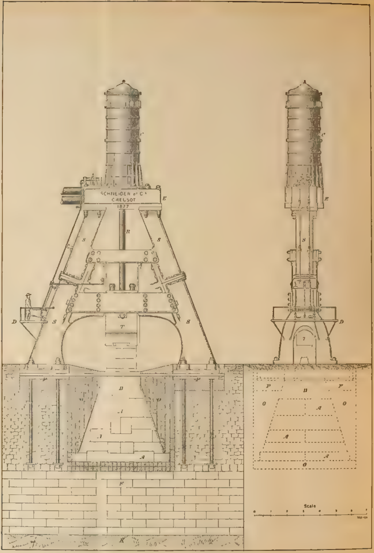


LE CREUSOT.

placed at an angle with the center line of the shop, in order to facilitate the handling of the ingots to and from the furnace by the cranes. A railway of 1.44m.-gauge runs through the center of the building, and is provided with the necessary crossings and points to enable trucks to approach cranes, furnaces, and hammer.

The *hammer* may be said to consist principally of four parts, the foundation or substructure, the main supports S (Plate XLV.), forming the guides and cylinder supports with the entablature E on which the cylinder rests, the cylinder C with its valves, and the tup T and rod R. The foundations consist of a mass of masonry in cement, resting on the rock K, 11m. below the ground surface; an anvil-block of cast-iron, resting upon a mass of oak O, designed to absorb, by its elasticity, as much as possible the vibration due to the shock, which would otherwise be injuriously transmitted to considerable distances. The masonry comprises a mass of 600 cubic metres, the upper part being covered with the bed of oak planks to a thickness of about 1m., on which the anvil rests. At the Perm and other works, it has been found more convenient to cast the anvil-block in its place rather than make it in pieces, the anvil at Perm weighing about 600 tons. Messrs. Schneider consider that there are serious objections to these anvils so cast in one piece, and therefore determined to make theirs in six horizontal layers, the whole weighing 720 tons, and each layer A, being in two parts, except the top one, on which the anvil itself rests. This top layer B is in one piece, and weighs 120 tons. The block is 5.6m. in height; the area of the base is 33 square metres, and at the top 7 square metres, the space round it being filled in with oak. The anvil-block is entirely independent of the main supports S of the hammer. The latter, it will be seen, incline towards each other, and rest at the base on massive bed-plates P, to which they are keyed, and which rest upon the masonry surrounding the anvil. Each support is in two pieces, cast hollow, and of rectangular section.

The guides are cast separately, and fixed to the supports as shown by bolts, and the supports themselves are firmly connected by the wrought-iron plates seen in Plate XLV. The height of the supports is 10.25 metres, and their weight with the guides is 250 tons. The wrought-iron plates above referred to weigh 25 tons, and the cast plates upon which the supports rest weigh 90 tons. The assemblage of the supports and parts connected has been found by the experience gained since the hammer has been at work to possess great rigidity. The entablature E, on the top of the supports, weighs 30 tons, and the cylinder C, which it supports, is made in two lengths, each 2.5 metres in height, bolted together at the center. The distribution of the steam is effected by two single equilibrated valves. The diameter of the cylinder is 1.9 metres, giving an area of 27,345 square centimetres, deducting the area of the piston-rod, which is 36 square centimetres. This area, with a pressure of 5 atmospheres, gives a total pressure on the piston of 140 tons. As the weight of the parts to be put in motion is 80 tons, it will be seen that this pressure is sufficient to lift this very rapidly, and in the down stroke enormously to augment the effect of the blow by the weight itself. The stroke of the piston is 5 metres; this, multiplied by 80,000 kilogrammes, the weight of the falling mass, gives 400,000 kilogrammetres of useful work.



SCHNEIDER'S 80-TON STEAM-HAMMER AT LE CREUSOT.
ENLARGED IN 1882 TO 100 TONS

placed at an angle with the center line of the shop, in order to facilitate the handling of the ingots to and from the furnace by the cranes. A railway of 1.44m.-gauge runs through the center of the building, and is provided with the necessary crossings and points to enable trucks to approach cranes, furnaces, and hammer.

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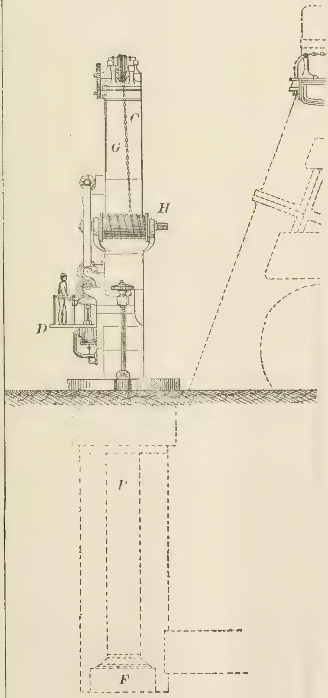
The width between the supports is 7.5 metres, and the free height under the lower connecting plates, 3.2 metres. There is thus plenty of room for the manipulation of the enormous blocks with which the hammer will have to deal. The height of the hammer from the foundation-plate to the top of the cylinder is 18.6 metres, and adding the height of the anvil-block, 5.6 metres, and that of the masonry supporting it to this, the total height of this giant structure is nearly 30 metres. This great height is, of course, an objection, as it tends to reduce the stability of the hammer, but the whole has been so well proportioned, and the cushion beneath the anvil-block is so efficient, that perfect rigidity has been secured, and the vibratory effect of the shock at a given distance is less severe than with the smaller hammers. The valves are operated by means of rods and levers brought down to within the reach of an attendant standing upon the platform D, fixed at about three metres above the ground surface, and upon which he is protected from the scorching heat of the forging.

The *cranes* are of the same type but of different powers, three of them being capable of sustaining 100 tons and one of sustaining 160 tons. They are of the revolving-post crane class, and are very much like the 80-ton crane erected at Woolwich dockyard by Messrs. Rennie. The post P (Plate XLVI.), and gib G are formed in one bent-plate girder, supported by a foot-step, F, and revolving in a ring of friction rollers near the ground surface, and carried by a casting firmly fixed to the masonry well, and tied to the foundation-plates of the hammer. As all the cranes are thus fixed and tied to the hammer bed-plates, the strains due to each are largely balanced, and this assemblage of the whole secures great rigidity. From the pivot to the head, each crane is 17.4 metres in height, the height from the footstep to the ground level being 8.4 metres, and from the ground to the head, 9 metres. Each crane is capable of four movements by means of the small attached double steam-cylinder engines, E, which when running at 250 revolutions per minute, develop about 60 horse-power. The four movements are: (1) Swinging, (2) Lifting, (3) Traversing, (4) Rotating the load. The first three motions are nothing special; they are given by means of worm, bevel, and spur-wheels. The load is suspended from an immense bridle, B, the sling-chain running over a large sheave S. The lifting-chain C passes over a series of wheels arranged to permit the third motion, and is wound upon a helically-grooved barrel H. The third motion is effected by means of a pitch chain. The fourth motion is one of novel application, but one which is absolutely essential in handling large masses. It is that by which the piece being forged is turned over and round upon the anvil, and by its means a 100-ton forging will be turned with facility, while a forging of a few tons at present requires a small army of men for its manipulation. The movement of rotation is, it will be seen, effected by means of a telescopic shaft connected to the engine and to the sheave referred to by means of universal joints, J, known in this country (England) as Hook's joints, and on the Continent as Cardan's joints, by means of which the shaft may follow the vertical movement of the load, its length altering in accordance with the motion of translation by means of its telescopic form. The weight of each of the 100-ton cranes is 110,000 kilogrammes, and of the 160-ton crane, 140,000 kilogrammes.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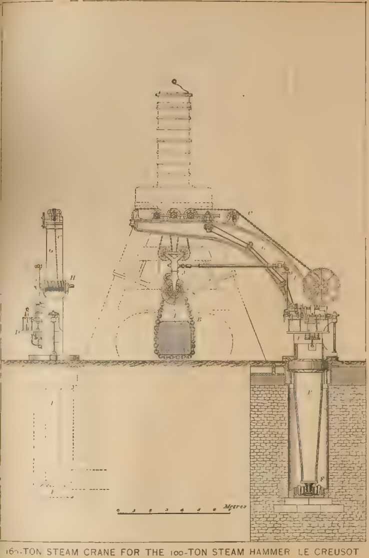

160-TON STEAM CRANE FOR THE 100-TON STEAM HAMMER LE CREUSOT

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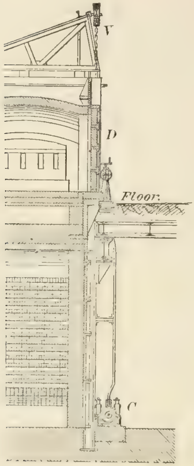
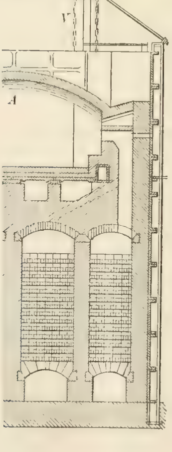




AL SECTION.

The operator stands on a platform D in front of the engine, where he has command of all the levers, by which he carries out the orders of the smith. The steam required by the hammer and by the cranes is provided by a battery of eight steel boilers of the Lancashire type, which also provide steam for the other hammers and for the engine driving a rolling-mill.

The *furnaces* F (Plate XLVII.), in which the masses of metal to be dealt with are heated, are of the Siemens regenerative class. The fire occupies a space of 7.8m. by 3.6m. by 10.m. in height. The interior dimensions of the furnace are 4.3m. by 3.4m. by 2.6m. in height under the arch A. The entrance for the introduction of the ingot or forging is 3.5 metres in length, and 2.3 in height, the door D, by which it is closed, being operated by means of the hydraulic-cylinder C actuating the chains V. The gas generators which furnish the gas for these four furnaces, as well as for a tire-mill and forge, are thirty-six in number, forming a battery of nine groups of four generators, situated at some distance from the shop.

The establishment of such plant is followed by the requirement of a train of secondary but of very important apparatus. For instance, it is necessary to provide special trucks to transport the ingots or forgings. Certain forgings in steel, such as guns, have to be submitted to other operations, to be turned, stacked away, &c., to facilitate which, it became necessary to erect a powerful 100-ton traveling crane running on rails 11 metres apart, and laid close up to the hammer.

The whole of this plant necessary for the production of large masses, from the casting of the ingot to the last operations at the forge, has caused an outlay of about 3,000,000 francs, or about £120,000. Though this is a very large sum, it will at least place Creusot far above the competitors of France or any other country for a long time, and the conception and realization by construction of so grand a plant reflects the greatest honor and credit upon Messrs. Schneider and their engineers.

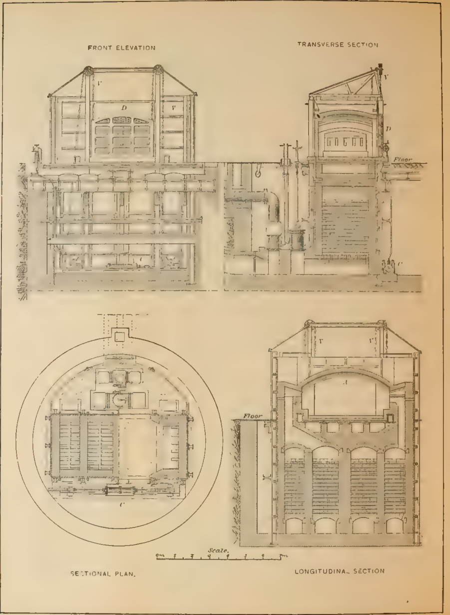
Principal Dimensions in Detail.

The hammer:

Weight of the moving mass	80,000 kil.

Dimensions of the parts above the ground level:

Length of full stroke	5.000 m.
Diameter of cylinder	1.900 m.
Pressure of steam	5 kilos.
Total pressure under the piston	140,000 kil.
Diameter of admission-valve	0.340 m.
Diameter of emission-valve	0.460 m.
Diameter of piston-rod	0.360 m.
Clear width between the tup-guides	1.900 m.
Clear width between supports	7.500 m.
Clear height under bracing-plates	3.200 m.
Length of the bed-plate	12.600 m
Width of the bed-plate	6.000 m.



HEATING FURNACE FOR THE 100-TON STEAM HAMMER, LE CREUSOT

The operator stands on a platform D in front of the engine, where he has command of all the levers, by which he carries out the orders of the smith. The steam required by the hammer and by the cranes is provided by a battery of eight steel boilers of the Lancashire type, which also provide steam for the other hammers and for the engine driving a rolling-mill.

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Clear width between supports	7.500 m.
Clear height under bracing-plates	3.200 m.
Length of the bed-plate	12.600 m
Width of the bed-plate	6.000 m.

Height of supports	10.250 m.
Height of cylinder	6.000 m.
Height of cylinder from bed-plate to the summit of the cylinder	18.600 m.

Dimensions of the parts below the ground level:

Height of anvil-block	5.600 m.
Area of anvil-block, base	33 sq. m.
Area of anvil-block, top	7 sq. m.
Number of horizontal layers in anvil-block	6
Number of pieces in each layer (except the top or anvil, which is in one piece)	2
Thickness of masonry between rock and anvil-block	4.000 m.

Weight of the superstructure:

Piston-rod, tup, and all moving parts	80,000 kil.
Cylinder	22,000 kil.
Entablature	30,000 kil.
Supports and guides	250,000 kil.
Bracing-plates	25,000 kil.
Foundation or bed-plates	90,000 kil.
Parts accessory to the mechanism	33,000 kil.
Total weight of all above ground	530,000 kil.
Anvil and block	750,000 kil.
Total weight of the structure	1,280,000 kil.

Cranes—Principal dimensions:

Three cranes, capable of sustaining	100,000 kil.
One crane, capable of sustaining	160,000 kil.
Radius commanded by each crane	9.350 m.
Height between ground and rails carrying carriage	9.000 m.
Height between ground and footstep	8.400 m.
Total height	17.400 m.
Power of each engine	60-horse.
Diameter of cylinder of each engine	0.260 m.
Stroke	0.300 m.
Number of revolutions per minute	250

Cranes—Weight:

Metallic part of 100-ton crane	110,000 kil.
Metallic part of 160-ton crane	140,000 kil.

Furnaces—Exterior part:

Length over all	7.800 m.
Width	3.600 m.
Total height	10.000 m.

Furnaces—Interior part:

Length	4.300 m.
Width	3.400 m.
Height	2.600 m.

Furnaces—Entrance:

Length	3.500 m.
Height	2.300 m.

The building—Principal dimensions:

Length	50.00 m.
Width	35.00 m.
Height below the springing of the rafters	17.00 m.
Height below the ridge	25.50 m.
Height below the lantern	28.30 m.

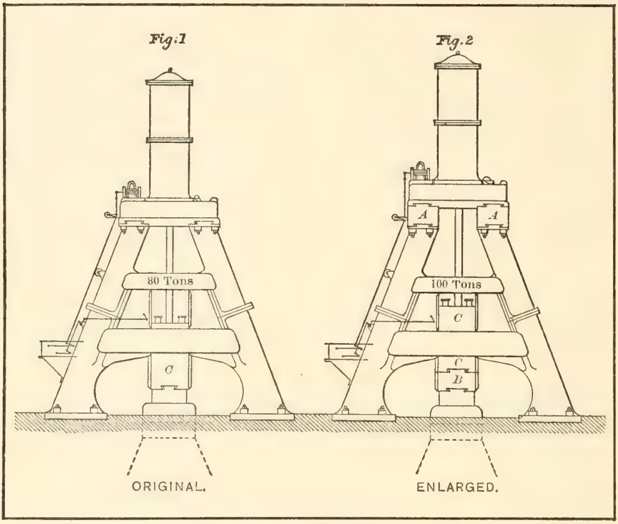
Note.—Kilogramme = 2.2046 lbs. Metre = 3 ft., 3.37 inches. Kilogrammetre = force required to lift 1 kilogramme to the height of 1 metre.

Although the moving mass weighed but 80 tons, a pressure of 140,000 kilogrammes was developed under the piston-rod, and this remarkable tool has been worked nearly every day without an accident.

It being generally accepted, however, that the blow of the striking mass, actuated by steam pressure through the length of its stroke, is not so effective as the pressure of a heavier tup, forging the ingot by its falling weight, and that the former interferes with the molecular flow of the heated metal, Mr. Schneider decided to increase the weight of the tup to 100 tons.

To do this, the weight of the striking mass C, page 704, figures 1, 2, was increased by adding the block B, figure 2, one metre in height, of the same section as the portion C, and weighing 20,000 kilogrammes. In order to retain the same length of stroke, two rectangular pieces A, each one metre long, were inserted between the upper ends of the supports, or jambs, and the entablature. Figures 1, 2 represent the original and enlarged hammers. The power gained is about one-fourth, and the present effective working force, without the steam pressure above, is represented by the height of fall, 5 metres, multiplied by the 100,000 kilogrammes of the mass, which equals 500,000 kilogrammetres, or about 1640 foot-tons.

When the immense building was constructed for the forge, the question of enlarging the hammer was considered, and sufficient space was allowed for a reasonable increase of height; consequently, when



SCHNEIDER'S 100-TON STEAM HAMMER AT LE CREUSOT.

the change was made, no alterations to the covering and its supports were necessary.

The 100-ton hammer has worked as easily and satisfactorily as the 80-ton, and France possesses in her great works of Henri Schneider and Company, Le Creusot, the most effective *steam-hammer* in the world.

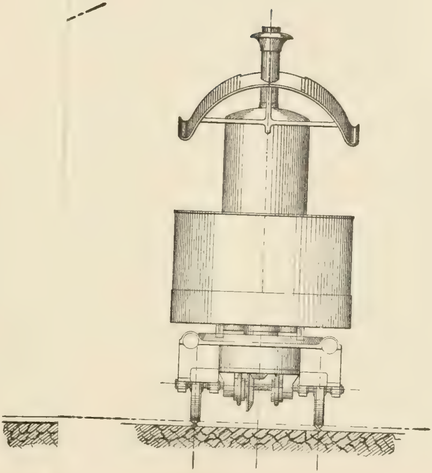
Of the many useful cranes about the establishment, the most remarkable and handy was the *Schneider Portable Steam-Crane* (Plate XLVIII.)

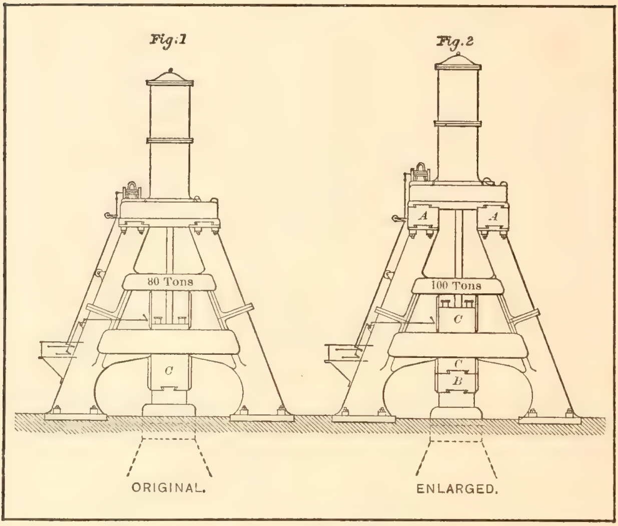
LEGEND.

Nominal power	7 tons.
Maximum range of jib	8 metres.
Minimum range of jib	3 metres.
Heating surface of boiler	9 square metres.
Effective steam pressure	9 kilogrammes.
Weight of crane	19,500 kilogrammes.

It has five independent movements :

1. Lengthening and shortening of the jib.
2. Lateral movement of the jib.





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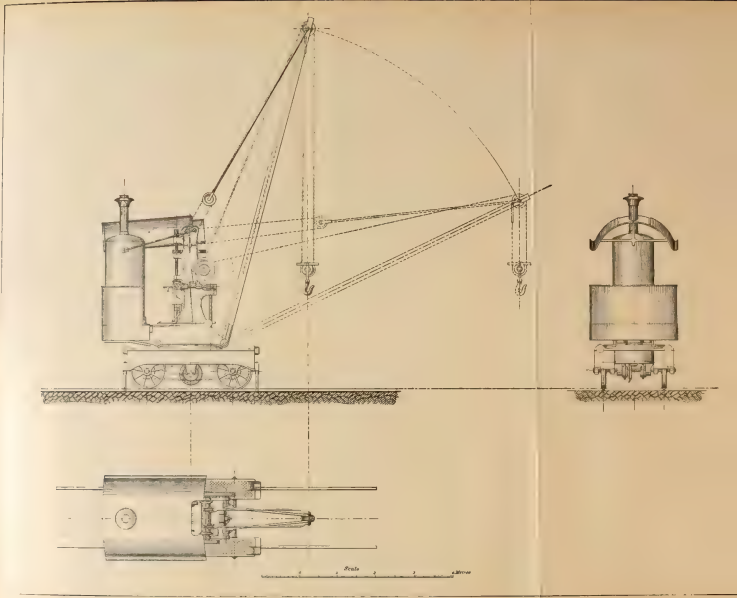


SCHNEIDER'S PORTABLE STEAM CRANE.

3. Lifting.
4. Motion of translation.
5. Brake to govern the load raised.

Distances included between the load and the axis of the crane's pivot.			3 metres Minimum.	8 metres Maximum.
Weights the crane will lift.	Crane clamped to the rail.	Longitudinally	10,000 kilos.	3,500 kilos.
		Laterally	6,500 "	2,300 "
	Crane unclamped.	Longitudinally	7,000 "	2,500 "
		Laterally	4,500 "	1,600 "

These are the weights that the crane will lift when clamped to the rail, under good conditions. If these are surpassed, there are risks of tearing up the rail or upsetting the crane.

The *Construction Shops* (Plate XLIII.) are 1640 feet long with an average width of 490 feet, and contain iron and bronze furnaces, hand forges, brasiery, steam and other mechanical cranes; hydraulic riveters and presses; 27 small steam-hammers for forging parts of moderate size suitable for marine engines, locomotives, steamboats, etc., and parts of cannon of small calibers; departments for boring, turning, planing, adjusting, and assembling; all fitted with powerful tools, kept up by additions and modifications to the most recent progress in each particular industry, and economizing labor, increasing production and educating the workmen to that precision which France demands of her mechanics.

These shops also include sections set apart for the fabrication of cannon, and where the forged parts are machined and assembled. They contain excellent turning, boring, rifling, and finishing lathes capable of fabricating guns from the mountain-piece of 200 pounds to the naval monster of 100 tons, and from a yard in length to 50 feet.

One of the most important annexes of Le Creusot is the *Ship-yard and Construction Shop of Chalon-sur-Saône*, where are built bridges, caissons, beams, frames, hulls of ships, barges, dredging-machines, material for railways and river steamers, in addition to a large production of iron and steel for other commercial purposes. Many gun-carriages are also manufactured here.

Among the famous structures that have been produced here are the Viaduct of Fribourg, the bridge at Brest, the large bridges across

the Danube at Vienne and Luiz, the drawbridge of Missiessy at Toulon, and the magnificent arched bridge at El Cinca in Spain.

As an indispensable complement of a manufactory of armor-plates and guns, Le Creusot possesses a *proving-ground* where her artillery products are tested. This polygon, a short distance from the works, is connected with them by rail and telegraph, and is well equipped with earthworks, casemates, magazine, gun-platforms, targets, and ballistic instruments.

The principal *railway* is situated between the forge and the steel-works. From this, branches radiate in all directions. There are also special lines connecting the works with the Central Canal and the Mazenay mines, and branches that join its private roads to those of the State. The rolling-stock includes 17 locomotives of from 25 to 38 tons, and 700 cars of different types, of from 10 to 100 tons capacity, fitted to meet the various requirements of the different departments.

The continual development of the workshops and their tools was but a part of the immense task that the Messrs. Schneider undertook. To utilize properly this vast plant, they needed an efficient *personnel.* The district could not provide this, for, in 1837, Le Creusot was a neglected village of only 3000 souls.

As the workmen had to be brought from a distance, it was necessary so to establish and provide for them that all commercial and political crises could be met. Aided by the people whom they have educated and for whom they have so well cared, Messrs. Schneider have been enabled to meet every emergency without Government or private aid, and the little hamlet of Creusot has been transformed into a populous center of 30,000 contented people. From its population the working force is supplied.

At first, the administrators erected houses and rented them to the workmen at moderate rates ; but by degrees this system was given up and the employees were permitted to own their homes, meeting the payments by a reserve of wages. In 1851, there were 390 such homes and two large barracks for lodgers. These barracks have since given way, one to the new site of the steel-works, the other to the workmen's village of Villedieu, composed of some 2000 houses, rented for 5 per cent of their value, with the privilege of purchase. They are well built, ventilated, and lighted, situated upon spacious streets and surrounded by promenades and parks.

To meet the demand, the water from the neighboring hills and the

condensed supply from the shops were collected in *reservoirs*. The constantly increasing consumption, augmented by the requirements of the new forge, was met by leading the waters of Saint Sernin and the turned Rinsçon by pipes, a distance of 14 miles.

The *oil lamps* have long since given place to an excellent system of *gas-lighting*.

Each employee receives gratuitous medical attendance for himself and family, besides pecuniary aid in cases of necessity. The first *hospital*, proving too small, was replaced by another, excellently adapted to the needs. Its staff is composed of several physicians and surgeons, who, aided by sisters of charity, attend to all the wants of the sick.

At first, these expenses were met by a small levy upon the wages of the workmen, but they are now paid by the company.

Recognizing the effect of *education*, discipline, and religious association, excellent schools and churches have been provided in different parts of the town, and intelligent teachers have been selected. Though education, in one sense, is not obligatory, it becomes so in another, because no one is received at the works who cannot read and write. To give additional encouragement, each year the most advanced pupils are presented for admission to the School of Arts and Trades at Aix.

The power and prestige of the system of education at Le Creusot, and the influence it has had upon the development of the works, are prominent among the other most excellent characteristics of this great establishment. The wages, the rates of which are always increasing according to length of service, can produce no irritation. In addition to his daily pay, each operator is rewarded for the amount and excellence of his labor, and a record of it is published for the examination by all; nowhere else can there be found more intelligent and skilful workmen, or an element freer from artisan strife or trade quarrels.

By the system to which Messrs. Schneider have given so much attention, and for which they have expended such vast sums of money, there has been established at Le Creusot a class of intelligent people who comprehend the responsibility of success, and appreciate the provisions made for their comfort and happiness; and with great pride they aid the work to the utmost of their ability.

> "The manufacture of steel armor-plates is a specialty of Le Creusot, which is engaged in an active competition with the

manufacturers of compound-armor. Plates up to 60 centimetres in thickness and 3 metres wide are forged here." *

Lieut.-Colonel Abbot has described in the following words the operations:

All these armor-plates are forged by the 100-ton hammer, the largest in the world. The ingot we saw treated (75 tons) had been heating about forty hours. We were informed that it would be reduced in thickness from 1.4 metres to 0.55 metre by about a dozen successive hammerings, requiring ten days in all. The area of the face of the tup was about $6' \times 1.5' = 9$ square feet; its weight was 100 tons; and its fall was 5 metres, or less as desired. The porter bar for moving the ingot was a massive iron beam about a square foot in cross section. It served both to direct and to counterpoise the ingot, the hold of the crane being adjusted to effect the latter object. To prevent the vibration from breaking this huge porter bar, it had been warmed by suspending fires under it.

When the crane took the weight, a crowd of men with bars, engaged in square nuts slipping on the beam, directed the white hot ingot under the hammer so that the blow would fall on one side, and near the sinking-head end. After a few preliminary aims the blow fell, then another harder, and then a couple from the full height. The concussions were tremendous, and an indentation about 6 inches deep, and the full size of the head was made about two-thirds across the plate. The latter was then drawn back, and a similar dent was made by the side of the first. This operation was repeated until the forging extended to the end of the ingot. The remaining third was next treated in the same manner, reducing the whole to a uniform thickness of about 4 feet. The end showed two slight bulges, the lines of greatest extension being about a foot above the bottom, and a foot below the top. The action of the hammer evidently extended to the middle of the mass, but not quite so effectually as at points nearer the seat of the blow. The spectacle of this forging was grand beyond words, especially as seen at night by its own light.

"The plates are tempered after forging, but what subsequent treatment they receive was not explained.

The tempering-pit for the plates consists of an excavation of convenient size, in the center of which is placed a tank containing 180 tons of oil. At the four corners of the pit are furnaces in which the plates are raised to a proper temperature. When sufficiently heated, a plate is seized by a walking-crane and immersed in the oil." *

The rivalry between the advocates of "all-steel" and "compound-armor" has been greatly heightened by experiment and by the strong opinions of the Italian Minister of Marine; and though these last were pronounced in favor of the steel-faced English plate, the follow-

* Gun Foundry Board Report.

ing correspondence and the tests of the armor for the Furieux, pages 712, 713, indicate that the Schneider plate has not yet been equalled in the two great requisites for naval use, "protective power, with the least possible weight."

LE CREUSOT, FRANCE, *Nov.* 26, 1883.

SIR: We have seen your personal letter of the 6th instant to M. Simon, in which you ask if it is true that we declined (see page 622) the programme of tests that the Italian Navy adopted, after the Spezia trials in November, 1882, and which we enclose.

In reply to your question, we have the honor to inform you that we have had no occasion to decline this or any other test, for, since the trials of November, 1882, the Italian Navy has not addressed a word to us on the subject. Far from having refused this test, we have on the contrary voluntarily submitted to the Italian Navy a programme of trials justified by our complete success at Spezia, and the confidence we have in the strength of our plates.

To dispel all misunderstanding on this point, we think we cannot do better than to send you, herewith, a copy of our letter of March 5, 1883, to His Excellency, the Italian Minister of Marine, which contained our proposition.

As you have stated, after such a proposition, we could have had no motive for refusing the new programme adopted by the Italian Navy, if it had been proposed to us.

Besides (as Lieut. Very properly stated in his interesting work) at the time of the Spezia trials in November, 1882, the contracts for the plates of the Italia were already made, so that these trials could have no immediate effect as far as we were concerned and could only serve to establish new conditions of acceptance in case the Italian Navy were required to make new contracts, or desired new trials.

Neither of these cases took place, and, consequently, we have not had to resume the consideration of this question with the Italian Navy. The only conclusion to be drawn from these trials is, in short, the following: The Italian Navy has recognized that the compound plates could not stand tests like those of Spezia, and although these tests were those that the contracts required of the manufacturers, the Italian Navy has modified them for the reception of the rest of the Italia's contract.

It is in conformity with this new programme, as you no doubt know, that in September last the tests for the receipt of the supply of armor for the Italia were made at Spezia on two compound plates of English manufacture. The two plates were badly broken, and it appears from our information, that after a single shot the plates were more ruined than ours were at Spezia after two shots.

We think that this information will interest you, and hasten to give it to you however incomplete it may be. . . . . . .

Our letter to the Italian Minister of Marine is not confidential; on the contrary, we shall be much pleased if you will make its contents known to the

U. S. Navy Department, as well as to the Commission (Gun Foundry Board) that visited us.

Allow me to remain, your most obedient servant,

SCHNEIDER.

Lieutenant W. H. JAQUES, *Newark, N. J.*

[Copy.]

PARIS, *March* 5, 1883.

SIR :—From an extract in the *Rivista Marittima*, and an article in the *Italia Militare*, of February 24, we have learned some conditions of tests which will satisfy the Firing Board of the Royal Navy and the Naval Superior Council for the reception of the plates destined for the armor of the Italia.

According to the *Italia Militare*, the Naval Superior Council believed that "the compound plates which would stand victoriously this test would protect the Italia, at least, as effectually as the Schneider plate last tried at Spezia."

If this is indeed the opinion of the Council, we regret that this high authority was declared without calling upon us to submit the highest tests that experience would allow us to accept.

We believe, therefore, it will be agreeable to your Excellency and useful to your administration to inform you in this letter of these conditions.

I am, Sir, respectfully yours,

SCHNEIDER ET CIE.

To His Excellency, Vice-Admiral ACTON, Minister of Marine, Rome.

PROGRAMME OF TESTS FOR THE RECEPTION OF COMPOUND PLATES FOR THE ITALIA. PROPOSED BY THE PERMANENT COMMITTEE ON WAR MATERIAL AND ADOPTED BY THE ITALIAN MINISTER OF MARINE. EXTRACT FROM A REPORT OF THIS COMMITTEE PUBLISHED IN THE *Rivista Marittima* OF FEBRUARY, 1883.

The Committee is of the opinion that for the compound plates intended for the Italia, the following tests are established :

1st. The plate selected for the firing test shall be secured to a wooden backing of about 80-cent. thickness in a way the manufacturer shall think most suitable.

2d. The plate shall receive in the center a Gregorini chilled shot, fired from the 45-cent. (100-ton) Armstrong rifled cannon (M. L. R.), with a force equal to that required to penetrate an iron plate of 25 per cent greater thickness. The projectile energy shall be determined by the well-known Muggiano formula.

3d. The shot must not go through the plate at this blow, and, notwithstanding the cracks that may be produced, no piece must be detached from the backing.

TESTS THAT MESSRS. SCHNEIDER & CO. WOULD ACCEPT FOR THE RECEPTION OF ARMOR-PLATES ORDERED BY THE ITALIAN ROYAL NAVY.

1st. The plate selected for the trials shall be about the same dimensions as those tried at Muggiano, in November, 1882; may be either flat or curved; shall be secured and held to a wooden target of the same kind, in a way most suitable to Messrs. Schneider & Co.

2d. The plate shall receive at the apexes of an equilateral triangle of 1.25m. side, placed in the center of the plate with one side horizontal, three rounds with a service Gregorini chilled shot fired from the (45-cent. A. R. C.) 100-ton Armstrong rifle with energies—for the first round, with a force required to penetrate an iron plate of the same thickness; for the second and third rounds, with a force required to penetrate an iron plate of 25 per cent greater thickness. The projectile energy of each blow shall be determined by the well known Muggiano formula.

3d. None of the shots must go through the target, and notwithstanding the cracks that the first two rounds may produce, no piece must be detached to expose the backing. After the third round, projections of pieces of the plate may partially expose the backing.

[Signed] SCHNEIDER & CO.

Tests of Armor-Plates for the Furieux.

The plate tested July 13, 1883, at the French proving-ground at Gâvre, was manufactured at Le Creusot in the usual manner. It was 3.001 metres long, 2.319 metres wide, and from 411 to 459 mm. thick, and weighed 23 tons, 9 cwt. It was secured by 20 bolts, according to the Schneider system, to a wooden target of the form required by the Gâvre Committee.

Three shots were fired from a 32-cm., model 1870, Navy B. L. R., at the apexes of an equilateral triangle, whose base was horizontal and 800 mm. long. The projectiles were chilled shot, weighing 345 kilos.

The first and second shots struck the plate at points 423 mm. thick, with a velocity of 431.7 metres, page 712. The third shot struck the plate at a point 439 mm. thick with a velocity of 442.6 metres, page 713.

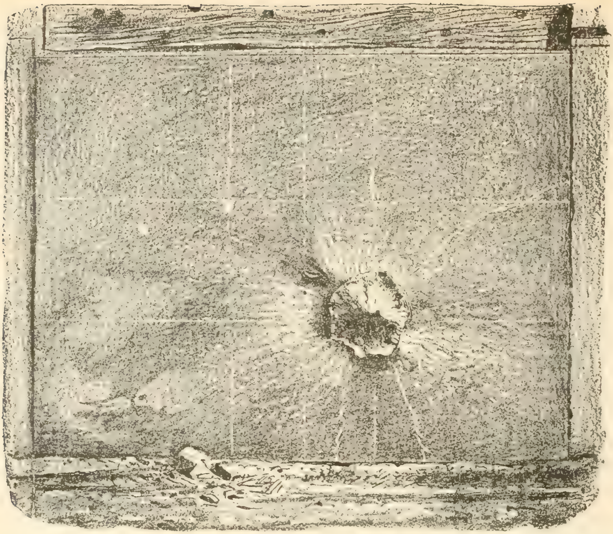
The projectiles were broken up, all the bolts remained intact, no portion of the plate fell from the backing, and the tests as proposed, pages 710, 711, were more than met.

> " Hoops for cannon are manufactured here in large quantities. They are cut from solid ingots, and those for guns up to 24 centimetres are rolled like railway tires; those for larger calibers are forged on a mandrel." *

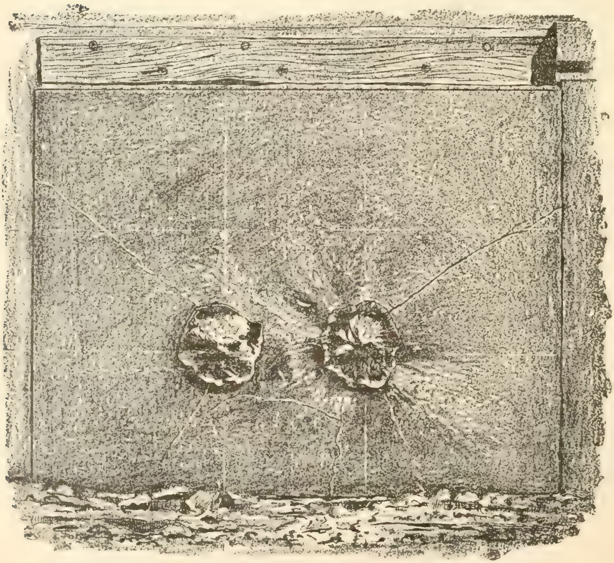
The following extracts from the report on metallurgy at the Paris Exhibition of 1878, and from the Revue d'Artillerie describe the manner of fabrication:

Fabrication of *Frettes* (Hoops).—By casting the steel in moulds of suitable dimensions, solid cylinders are obtained, which are flattened into disks under a

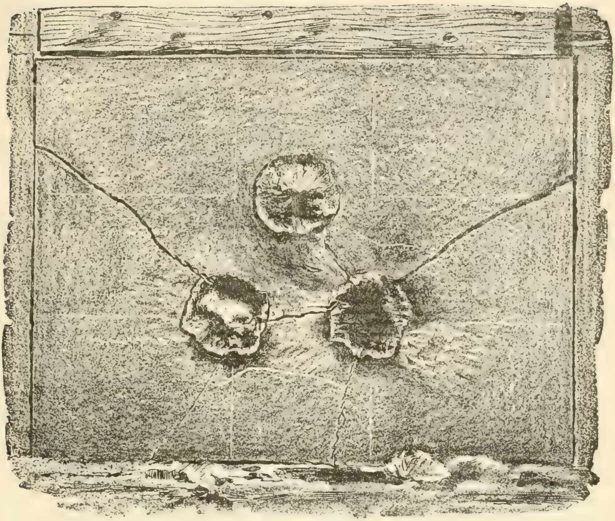
* Gun Foundry Board Report.



FIRST SHOT.



SECOND SHOT.



THIRD SHOT.

hammer. While still warm, they are placed under a second hammer whose face is terminated by a mandrel, so placed as to punch in the center a cylindrical hole. In this state the frettes are subjected to various rollings (in machines such as are used for rolling steel tires) so as to gradually enlarge the interior diameter and diminish their thickness.

Ordinarily, the frettes are rough drawn and finished in the rolling machine ; but sometimes only the roughing is done in the machine and the frettes finished under the hammer. During this last operation, they are mounted upon an iron mandrel attached to the anvil.

* * * * * * * * *

Ingots for tires are often cast in an octagonal shape as if for rails ; in other shops, in order to avoid the seams, they are cast in moulds which give them a round flat shape.

In every case, when the ingot has reached a suitable temperature, it is flattened under a hammer, and it is then rounded, if possible, so that after the first heat it may be in the shape of a circular disk, of a thickness varying with the height of the original ingot, and the work to which the steel may be subjected in a single heat. This disk is carried to the re-heating furnace, and when it has acquired a suitable heat, it is flattened under the steam-hammer to the required thickness, and prepared for the operation of punching the hole.

This operation is performed in two ways. In some shops the hole is pierced in the disks by means of a conical punch attached to the face of the steam-hammer, the disks being turned three or four times, an operation to be carefully performed, in order to assure the centering of the hole, and to avoid the formation of cracks.

In other works, the hole is made with steel punches from 5.9 to 7.87 inches diameter, forced in under the hammer. The metal is upset by the operation, and a hole is obtained from four-tenths to eight-tenths inch greater in diameter than that of the punch.

This method causes a loss of material, but has the advantage over the others of straining the metal less, and permits a nearer approximation to the required weight of the ring. As a fact, ingots cannot be cast with great exactness, and there are always slight differences; but by weighing the ingot before the hole is made, the weight of the piece to be punched out (and consequently the diameter of the punch itself) can be determined, which will bring the ring to the required weight.

The ring so obtained is at once placed upon the beak of an anvil, under a steam-hammer, so inclined that not alone will the ring be enlarged, but will be given on one side a conical form, approaching that it will ultimately receive.

The ring is thus drawn out up to half of the finished diameter, being turned on the anvil by means of a lever, and then removed to another hammer to be flattened exactly to the required thickness. The ring is then allowed to cool, and little irregularities corrected with the hammer and chisel. The ring is then rough-finished in two heats.

Rolling.—The rings are then placed in the re-heating furnace, and when they have acquired a suitable temperature, transferred to the rolling machine. Two classes of these machines are in use—those with horizontal and those with vertical cylinders. The former are the more simple in construction, but they do not make the tires sufficiently symmetrical, and it is afterward necessary to mandrel, an operation which is apt to affect injuriously the quality of the steel. With certain of the machines with vertical cylinders, it is possible to produce tires which are absolutely round.

* * * * * * * * *

"Jackets of large size are also manufactured; these are made from solid ingots, which, after being forged, are bored out.

At Le Creusot, a remarkable test of hoops was witnessed which exemplifies not only the excellence of the manufacture of the steel but also the exacting character of the French requirements. The hoops for naval guns are made with the interior surface slightly conical. When forged, turned, and brought under a hammer, a standard mandrel of steel, conically shaped to suit the form of the cone in the hoop, but of a slightly increased diameter, is introduced, the smaller end of the mandrel being able to enter the larger end of the hoop. The

mandrel is then forced in by the hammer until its lower edge has passed through the hoop. The blows are then made to operate on the upper edge, detaching it from the mandrel. Careful measurements are taken of the diameter of the hoop before and after this test, and it is required that the measurement subsequent to the operation shall show that the hoop has partially, but not entirely, returned to the diameter that it had before the entrance of the mandrel. This would show that there is left to the metal a small margin within its elastic limit. A system of manufacture which can comply with such a refinement of exactitude must be very precise.

The process of tempering the gun-tubes was also witnessed by the Board. The excavation of the pit is, as at St. Chamond, 15 metres deep, with the furnace at one end and the oil tank (100 tons) at the other. One side of the upright furnace is constructed in the form of a door, which, by a convenient arrangement for swinging, is made to turn on its hinges. Thus, when the tube is raised to the right temperature, it is seized by the travelling-crane, the door of the furnace swung open, and the tube at once advanced to the tank in which it is immersed.

All tubes are immersed in oil the second time, but at a temperature much below that to which they are raised at the first immersion. This process constitutes the annealing after tempering.

For the preparation of metal for cannon and armor-plates Le Creusot is thoroughly equipped. The iron is produced on the premises from the purest imported ores, and the manufacture of the steel is carried on by the most approved application of the open-hearth system with the Siemens furnace; the chemical and mechanical tests are such as to satisfy the most exacting demands of careful Government officials, and the executive ability apparent in all the departments and the evident condition of discipline that pervades the whole establishment inspire confidence in the productions of the labor." *

Of the apparatus used for testing, the principal machine is that manufactured by Schneider & Co. on the system of Colonel Maillard.

The machine and its accessories (Plates XLIX., L.) comprise the following:

* Gun Foundry Board Report.

The pump or compressor A, figure 3 (Plate XLIX.), connected with the machine proper, figures 1, 2, by the pipes P; the hydraulic cylinder B; the pressure-receiver C, mounted on a movable head D; a fixed head F, made in one with the cast-iron frame L, which supports all the parts; a Galy-Cazalat manometer (Plate L.); a cathetometer N, figure 2 (Plate XLIX.), furnished with a micrometer and two telescopes O, resting upon a support independent of the machine; and two Bourdon metallic gauges, which serve as additional indicators of the working of the mercurial manometer and the machine itself.

The *pump*, figure 3, is composed of a vertical barrel *a*, whose hollow piston *b*, supported by guides, has an interior thread to receive the screw *c*. A rotary motion is given to *c* by bevel gears and a revolving crank *d*. It is evident that with each revolution, the piston advances a distance equal to the width and pitch of the screw, forcing the water slowly, continuously, and regularly. The pump is connected with the hydraulic press of the machine by a copper pipe P.

The *cylinder* B, figures 1, 2, is fitted with trunnions M, so arranged that the cylinder oscillates around an axis perpendicular to that of the machine, passing through the test-piece. The trunnions rest upon bearings, which are part of the iron frame L. The piston *e* is connected with one extremity of the test-piece *f*, by the rod R, fitted with riveting clamps *d*, for this purpose. The other extemity of the test-piece is attached by similar clamps *d* to the pressure-receiver.

This *receiver* is composed of the coupling-link *m*, to which the test-piece *f* is attached; a piston *h*; the receiver proper *i*; a rubber washer *k*; and a metallic ring *l* secured to the receiver by bolts, keeping the rubber washer in place and serving as a piston-guide.

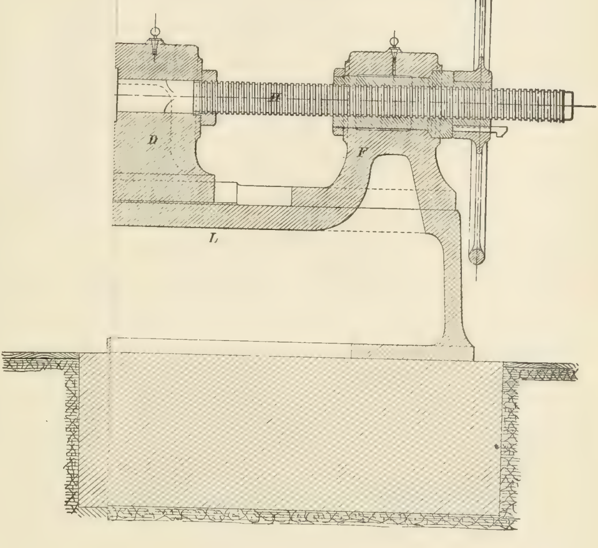
The strap *m* and the receiver *i* oscillate around two axes perpendicular to each other, so that the direction of the force exerted upon the test-piece coincides always with the axis of the latter. For this purpose, the receiver is fitted with the trunnions T, by means of which it is mounted upon a fixed support of the frame L. The strap *m* oscillates around the trunnions *t*, at the extremity of the piston *h*. The interior of the receiver is filled with water, and by a copper tube is in communication with the manometer.

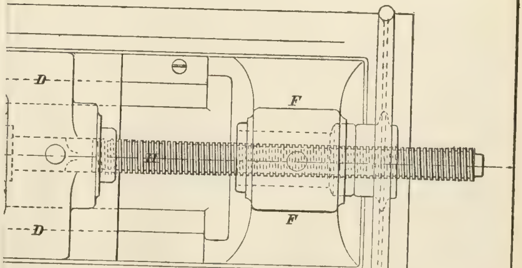
The movable head D, which slides upon the support L and carries the frame of the receiver, is actuated by the screw H turning in the support F. By this means the receiver is moved to accommodate itself to test-pieces of different lengths.

The Galy-Cazalat *manometer* is a mercurial gauge, whose trough or cistern A (Plate L.) is filled with mercury, and is in communication, by a pipe P, with a glass manometric tube T. The cistern is covered with a cap terminating in a small tube fitted with flanges on which is bolted another small tube B, fitted with a stuffing-box for the connection of a pipe leading to the receiver of the machine. A membrane D, of sheet rubber, rests upon the surface of the mercury. On this membrane there is a piston E terminating in a rod that forms a smaller piston F, working in the tube of the cap. Between this and the tube B there is another membrane G, also of sheet rubber.

By this arrangement, which prevents leakage, the pressure of the manometric column acting upon the surface of the piston E, and the pressure from the

FIG. 1.—LONGITUDINAL SECTION





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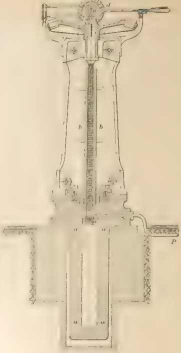


FIG 3

SECTION

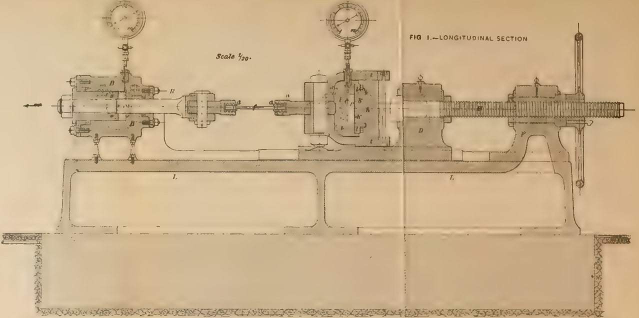
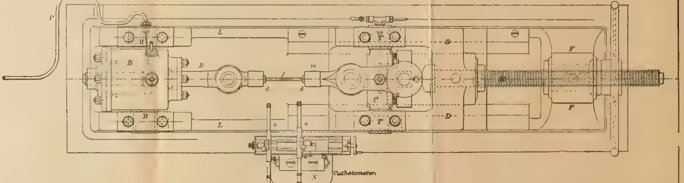
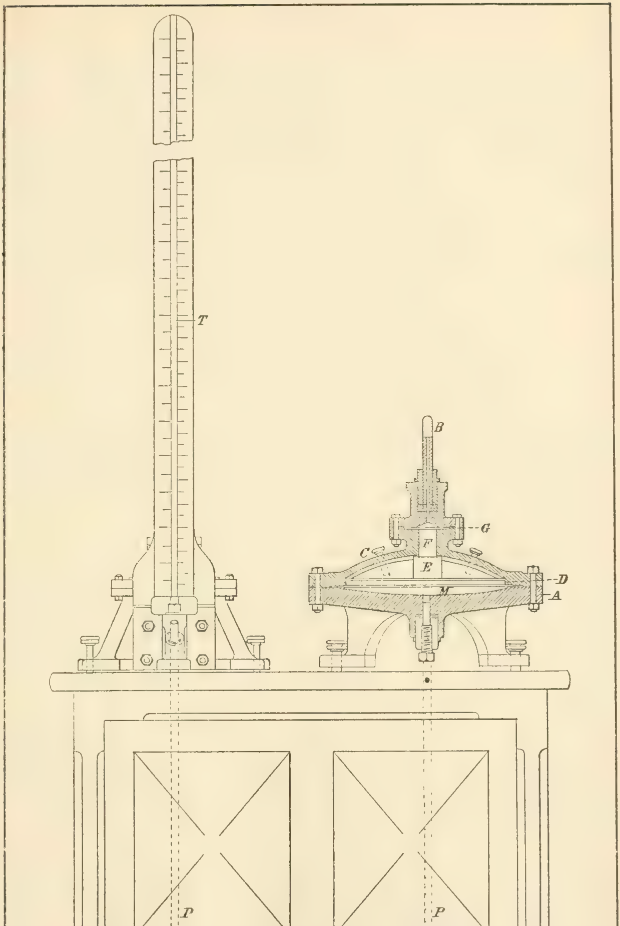


FIG 1.—LONGITUDINAL SECTION

FIG 2 —PLA



MAILLARD TESTING MACHINE.



GALY-CAZALAT MANOMETER.

receiver acting upon the piston F, are inversely proportional to their surfaces. The zero of the manometric column corresponds to the level of the membrane D.

To use the machine, the test-piece is put in place, as already indicated, and the pump is started. The water enters the cylinder B, figure 1 (Plate XLIX.), in front of the piston e, forcing it in the direction of the arrow. The test-piece receives a force that is transmitted to the receiver and thence integrally to the manometer. The object of the receiver is to transmit this force in its entirety. Being filled with water, which is incompressible, the pressure is transferred to the manometer without loss or change. The indicated manometric pressure is therefore equal to the tension of the test-piece.

Equation of Equilibrium.

S . . . . surface of the large piston.

p . . . . pressure per unit of surface upon it.

t . . . . surface of the small piston.

q . . . . pressure per unit of surface upon it.

n . . . . number of cubic decimetres in the manometric column.

13.6 kilogrammes = the weight of a cubic decimetre of mercury.

T . . . . surface of the receiver.

P . . . . Total tension of the test-piece.

The total pressure on the large piston will be pS.

The total pressure on the small piston will be qt.

The equation of equilibrium between the weight of the manometric column and the pressure coming from the machine will be

$$qt = pS;$$

but, $p = n \times 13.6$ kilos;

consequently, $qt = n \times 13.6 \times S$,

from which, $q = n \times 13.6 \times \frac{S}{t}$.

The pressure q transmitted to the liquid in the receiver, which has a surface T, gives a total pressure of qT, which is, of course, equal to the total tension P of the test-piece. Consequently,

$$P = qT = n \times 13.6 \times \frac{TS}{t}.$$

The section of large piston being so much greater than that of the manometric column, the movements of the large piston are slight. Those of the small piston are still more feeble, for the section of the receiver is so much larger than that of the small piston. Under these conditions, the membranes work very well.

By the employment of the manometer, all the conditions of test are easily followed, and the indications are continuous. When the test-piece is extended, its transverse section diminishes, and an equilibrium

is automatically established between the tension of the test-piece and the weight of the manometric column, the height of this column indicating the amount of tension. It therefore has a great advantage over the lever-machines, where the equilibrium has to be maintained by continually shifting the weights.

With the Maillard machine, the limit of elasticity is measured by the rise of the manometric column, and is deduced from an analysis of the particular circumstances produced during the elongations of the test-piece. For example, the stretching of a soft steel test-piece may be divided into four periods.

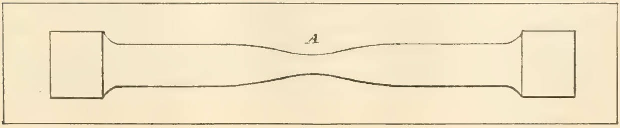
During the first, the mercury rises in the manometer rapidly; the elongations are very small, and sensibly proportional to the force that produces them. They are entirely elastic; that is, when the stretching power is removed, the test-piece returns to its original conditions.

During the second period, the mercury suddenly changes its velocity; it continues to rise, but slowly and with decreasing velocity. The elongations are greater than during the first period, are largely permanent, and increase more rapidly than the extending force. When this ceases, a very small part of the elongation disappears. The total extension is composed of the elasticity and the permanent set. The force corresponding to the stoppage or sudden change of the velocity of the mercury, without producing permanent set, represents the limit of elasticity. The elastic extensions produced by the forces beyond the limit of elasticity are proportional to them during the greater part of this period.

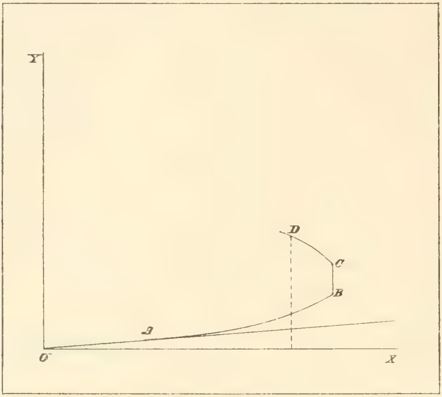
During the third, the mercury remains stationary and the test-piece extends under a constant force.

During the fourth period, the mercury descends, then falls suddenly. The test-piece stretches more and more, under the increasing force, its section diminishing very rapidly. It is drawn out and finally breaks.

The transverse sections vary at the same time as the longitudinal dimensions, and inversely. During the first and second periods, the test-piece remains practically cylindrical or prismatic, but in the third, and especially in the fourth, the variations in form are produced chiefly in a certain zone A, called a spindle, from the shape that the test-piece assumes.



All the conditions of test can be represented by a curve that indicates the elongations during the operation of stretching.



CURVE OF ELONGATION.

The abscissas represent the forces brought to bear upon the original section, that is, the quotient resulting from the division of the number of kilogrammes, representing the total forces, by the number of units of surface in the original section.

The elongations, taken as ordinates, are also relative to the unit of length, usually 100 millimetres.

The concave part of the curve, thus constructed, is always in the direction of the axis of Y, that of the elongations.

In the case of the soft steel, under consideration, the following are the principal points of the curve:

1st. The point A, corresponding to the limit of elasticity L. The part OA is a right line passing through the origin of the co-ordinates and inclined to the axis OY at an angle, of which the trigonometric tangent is $\frac{L}{i}$, i being the elongation corresponding to L. The expression $\frac{L}{i} = E$ is the coefficient of elasticity.

2d. The point B, which is determined by the maximum force and the least elongation produced by it.

3d. The point C, which corresponds to the greatest elongation

produced by the maximum force. The part BC is a right line, parallel to the axis OY.

4th. The point D, which corresponds to the rupture of the soft material. It is determined by the force producing the rupture and the corresponding elongations.

With the Maillard, the four points just mentioned can be noted immediately; but with the lever-machine, all the successive extensions must be measured, the curve traced, and the points then deduced from it.

To measure the progression of the elongations, a cathetometer N, figure 2 (Plate XLIX.), is employed. It consists of a carriage sliding in a socket parallel to the test-piece. The carriage is fitted with a micrometric slide and two telescopes O.

The test-piece being in place, the operators set the telescopes at marks upon it, the distance between which is indicated by a graduated scale. During the stretching, one observer follows his mark, moving the carriage with an adjusting screw. The other keeps his telescope on his mark by means of a micrometric screw. The graduations show, at any moment, the distance between the two telescopes, or the extension of that portion of the test-piece between the two marks.

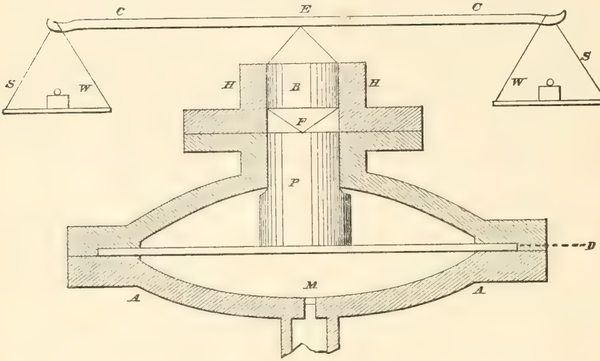
The telescopes are fitted with cross-hairs, which, with the vernier, are lighted by butterfly burners or small mirrors.

As the telescopes are sometimes very close together, one of them is fitted with prisms for side observation.

One *expert* observer is sufficient for the two telescopes. With this reduction, the number of observers required are one or two at the pump (one is sufficient when it is worked by steam or electricity), one to observe the elongations, and another to watch the dynamometric apparatus and register the results.

The apparatus is carried, as before stated, on a cast-iron pedestal, facing the machine and opposite the test-piece.

One great advantage of this system of testing-machine is that the manometer can be directly adjusted. This operation is performed, as shown in the following figure (page 722), by removing the movable tube (shown in Plate L.) and substituting another, H, that serves as a guide for the cylinder B, terminating at each end in a knife-edge. One of these edges, F, rests upon the piston P. On the other, E, a bar, C, is balanced, supporting at each end a scale, S, upon which weights, W, are placed.



ADJUSTMENT OF MANOMETER.

By varying the weights, the graduation of the manometric column is obtained, and a scale made that is independent of the variations of the diameter of the tube that contains the mercury. This adjustment, necessary in order to mark the scale upon the board to which the tube is secured, should be repeated from time to time.

In the preceding description, particular attention has been given to elongation tests. But the machine is equally suitable for tests of compression, bending, and penetration. All that is needed for these tests are special arrangements for attaching the sample piece to the cylinder-rod R (Plate XLIX.), and to the strap *m* of the receiver C.

The machine, with its accessories, is constructed for a maximum force of 60,000 kilogrammes, all that is required for ordinary practical tests.

Its advantages are:

Exactitude of tests.

Ease with which the different conditions of test may be noted, such as measurement of the limit of elasticity, and the determination of the principal points of the curve.

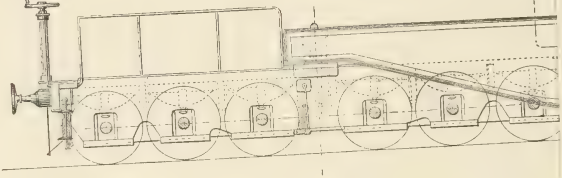
Easy adjustment of the dynamometric material.

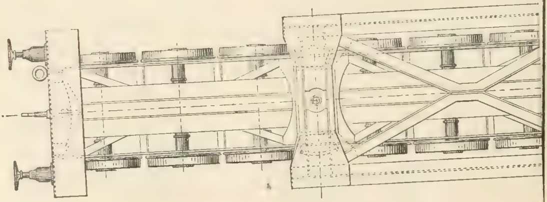
Rapidity with which the tests can be made.

A simple arrangement of all the parts renders them easy of access for inspection and adjustment.

The solidity of the frame absorbs the vibrations.

Its application to compression, bending, and penetration tests.





120-TON WAGON-TR

These machines are in use at the cannon factory at Bourges (France), the cannon factory at Trubia (Spain), the naval arsenal at Castellamare (Italy), and the royal arsenal at Woolwich (England).

For the transportation of very heavy guns by rail, Messrs. Schneider & Co. designed and constructed for the administration of the Turin Cannon Foundry a truck of new design and unusual capacity.

It consists (Plate LI.) of a wrought-iron bridge or platform, resting its extremities upon two bogies, each having six axles. The platform is attached to the bogies by two pintles, which, in transmitting shocks and the propelling force, allow the truck freely to follow curves of different radii.

The platform rests by means of friction runners, on circular archpieces, attached to the sole-bars of the bogies. The runners are so arranged that the platform can make a slight movement in the vertical plane, following the grade along the road. The platform is sufficiently elastic, even when empty, to bend transversely to meet inequalities of the road.

The passage of the bogies around curves of small radius is facilitated by giving a certain amount of side-play to the middle and ends of each axle.

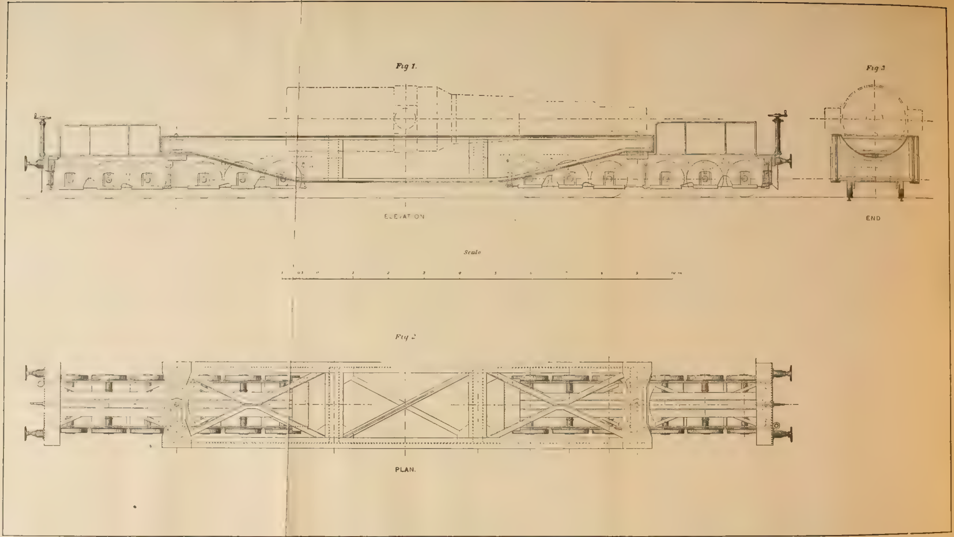
The gun is placed, with two oak pads between, on two thin breech and chase blocks, with just clearance enough to allow the axis of the gun to be as low as possible.

St. André crosses, suitably fitted, assure the horizontal rigidity of the body of the truck. The bogies are constructed with sole-bars strong enough to divide equally the weight among all the axles, and are provided at each outside end with a coupling and buffers. They are also furnished with a screw-brake with six shoes, and all accessories, such as a platform for oiling, handrails, steps, place for lights, etc., necessary for the convenience of service.

The bogies can be used separately for the transportation of guns of smaller calibre. In this case, a removable coupling is added to the interior end, similar to the one at the exterior, and blocks for supporting the gun.

During its initial trip from Le Creusot to Paris, carrying a weight of 67 tons, consisting of an armor-plate of 65 tons and its accessories of 2 tons, a velocity of 20 kilometres per hour was obtained, and the journey was made under excellent conditions.

The truck was constructed to carry a maximum weight of 120 tons.



120-TON WAGON-TRUCK AT TURIN GUN FOUNDRY ITALY—MANUFACTURED BY SCHNEIDER & CO, LE CREUSOT.

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"**Terre Noire.**—The 'Compagnie des Fonderies et Forges de Terre Noire, La Voulte et Bességes,' situated near St. Étienne (Loire), is one of the important steel-producers of France; and, though its metal has not as yet been received for tubes for large cannon, it has been largely used in the production of shells and hoops. The company claims a specialty in producing cast steel without blow-holes, which requires no subsequent working under the hammer. The mode of manufacture is known as the Terre Noire Process, and is the result of many years of gradual development. The value of the product has been so far appreciated by the Government as to justify its use for small guns and hoops, and even for trunnion-bands, while the manufacture of steel projectiles is a large item in the yield of the works. The Terre Noire metal is produced in the Siemens furnace, and possesses in the cast state all the necessary qualities for ordinary industrial purposes; it is soft and malleable, and is said to be as strong as ordinary steel of the same grade after rolling or hammering. It is claimed that its density is always as high as, and sometimes higher than, that of ordinary forged steel. These statements are supported by facts shown in numerous experiments." *

In 1875, Mr. Euverte, Director of the works of Terre Noire, prepared some notes that briefly recalled the following progress and results of the process:

For the past two years very important investigations have been made at the Terre Noire Works with a view to the use of phosphorus in the manufacture of steel. As far back as 1856 Mr. Bessemer made his first experiments, but the results were not satisfactory. Many scientific men declared then that the trials were made contrary to all existing theories, and that the new process could never succeed. From 1856 to 1862, Mr. Bessemer continued his investigations, and at the end of 1861 Mr. Gruner called the attention of metallurgists to the complete success of the new process.

At Terre Noire it was seen that the question was one of the greatest importance, and it was decided to thoroughly study it and persevere to a solution.

At the end of 1865, Mr. Bessemer called the attention of the Terre Noire Co. to the existence of works near Glasgow, Scotland, where ferro-manganese, containing from 25 to 30 per cent of metallic manganese, was manufactured; this was obtained by the process of Mr. Henderson.

Also, in the same year, the German industrial papers called attention to its manufacture by the process of Mr. Oscar Prieger, at Cologne. The ferro-

* Gun Foundry Board Report.

manganese made here contained 75 per cent of manganese, was manufactured in crucibles, and cost $1.20 per kilogramme.

Immediately experiments were made at Terre Noire with these alloys. The results were what were expected. With the ferro-manganese, a metal similar to the costly *homogeneous steel* was obtained, having only traces of carbon, and splendidly adapted to all industrial purposes.

The problem was theoretically and practically solved, but many efforts had yet to be made to arrive at a commercial solution. Meanwhile, for some reason, the production ceased in England; the German alloy was too costly. It would have been impossible to obtain ferro-manganese if the Terre Noire Co. had not secured the right to manufacture it in France. After many trials, the manufacture was established in 1869, and is to-day really an industrial undertaking. The Henderson process was taken as a basis, successfully improved, and since 1871 ferro-manganese, with 40 to 42 per cent of manganese, has been manufactured at Terre Noire for from 40 to 50 cents per kilogramme. New improvements are expected to give an alloy containing 60 per cent.

The problem is to-day solved, and the steel industry possesses the means of manufacturing an extra soft cast-steel, answering the required conditions of tension and elongation, of which plates, machinery, and cannon can be practically made and safely used.

The results of the numerous experiments made at Terre Noire show that the new metal possesses physical qualities of a peculiar nature and worth careful study. To keep within the bounds of truth, it may be affirmed to-day that *steel containing three-tenths of one per cent of phosphorus, and one and one-half tenths of one per cent of carbon, is very malleable, and can be utilized to make rails of very good quality.*

It may be said that a steel containing only one and one-half tenths of one per cent of carbon is not *steel.* This may be true; perhaps it would be well to modify the classification and not give the name of steel to a metal which contains almost no carbon, cannot be hardened, and behaves in so many ways like iron.

Already the French Navy has given the name of "Soft Metal" to the extra soft plates ordered from the works of Le Creusot and Terre Noire.

Special attention is now being given to the manufacture of large castings and the best methods of tempering and annealing. There are two 20-ton Siemens furnaces with the casting-pit between them. This arrangement is bad, because the intense heat injures the workmen. Gas is used in all the furnaces, and the shops are well equipped for heavy work. Cannon-hoops (*frettes*) of an interior diameter of 56 centimetres, and cylinder-linings, two metres in diameter and over two metres long, were in hand at the time of the Board's visit.

Mr. Pourcel, long associated with the process at Terre Noire, in a paper read before the Iron and Steel Institute at Vienna, referred in the following words to the progress recently made:

The studies still continued at Terre Noire are now being directed to two points:

1. The manufacture of large castings.

2. The methods of annealing and tempering to be applied to the metal, in order to give it all the mechanical properties corresponding to its chemical composition.

The end in view is the substitution of steel for cast-iron in all pieces of mechanical construction. But the final solution of this problem is still a long way off. The production of castings of any form and of any dimensions in steel of a well-determined chemical composition, combining the resistance and rigidity of steel with the smooth surface and homogeneity of iron castings, is a very complicated problem, and one which presents material difficulties of more than one kind.

The last progressive step made at Terre Noire is worthy of notice.

An engineering firm in Paris required some cylinders of cast-steel having a diameter of 2.04 metres and a height of rather more than two metres, with a uniform thickness of metal of 50 mm. These cylinders were to support an internal hydraulic pressure of forty-five atmospheres without showing any sign of percolation. The annealed metal was to have a minimum resistance of 50 kilos. per square millimetre, and a minimum extension of 8 per cent.

Of these cylinders, six have already been cast. The external surfaces of the castings are quite as smooth as if made of cast-iron, and yet the metal is comparatively soft. It contains on the average—carbon, 0.65 per cent; manganese, 1.00 per cent to 1.20 per cent; and silicon, 0.25 per cent to 0.30 per cent. It is, in fact, the quality demanded for rails by one of the French companies. The flanges of the cylinders, after turning, took a very fine polish, even at the gits, and were free from any defects. The metal is cast in moulds of loam, pierced with numerous holes to allow the gases to escape, and dried with great care. It is run in at the top of the mould, and not at the bottom, the time occupied in casting being less than two minutes. This particular point should be noticed.

The second point upon which the experimental studies of Terre Noire are being directed, comprises the various methods of annealing and tempering, applied for the purpose of assuring the molecular transformation of the metal, and of establishing the equilibrium of the molecules of a casting of prescribed form, and consequently of enduing it with the highest mechanical qualities corresponding to the chemical composition of the metal. We have here to conquer difficulties, not only purely mechanical, but others which are inherent in the solution of every problem pertaining to the domain of physics. You may make lots of experiments and possess numerous results, but it would nevertheless be imprudent to formulate a law which would not be, as every physical law should be, the synthetical expression of the deductions obtained from a very large number of concordant facts. It may, however, be of interest to the Institute to learn the practical results obtained in what is considered an extremely delicate manufacture, that of hoops (*frettes*) for cannon.

More than two years ago, Terre Noire supplied to the French navy a considerable number of hoops for guns of 10 centimetres. To-day we are working

on an order for hoops of the same type, the specifications for which are more severe. I am only speaking of round hoops, which are of the following dimensions:

External diameter	360	millimetres.
Internal diameter	246	"
Thickness of metal	57	"
Height	265	"

These hoops are cut out of a round ingot of 385 mm. diameter, cast solid in an iron ingot-mould, each ingot furnishing several hoops. The method consists in casting an ingot having nearly the external form of the finished casting, and then cutting out the surplus metal by means of powerful mechanical tools, to give the piece its definite form. In most cases, the rough casting would possess the dimensions of a rough forging; more metal is, however, generally left to be removed in the lathe. The metal in the head of the casting is, of course, not here taken into consideration.

A hoop is chosen from each ingot, sometimes from the top, sometimes from the bottom, and sometimes from the middle, from which are taken the samples for drop and tensile tests. This test-hoop is given rather more height than the others, viz., 310 mm. instead of 265 mm. The test-hoops are treated in the same manner as all those of the cast to which they belong; *i. e.*, they are heated and tempered in oil, according to a definite formula, and the test-cylinder, about 40 mm. high, is then cut in the lathe and forwarded to the Government works, where it is prepared for and subjected to the drop and tensile tests.

The bar to be subjected to the drop-test is of square section, 30 mm. $\times$ 30 mm., and 180 mm. long. It is placed on two supports or knives, 160 mm. apart; the anvil weighs 350 kilos. The bar must stand, without breaking, fifteen blows at least of an 18-kilo. monkey falling from a height of 2.75 metres.

The bars to be subjected to tensile tests have a diameter of 13 mm. and a net length of 100 mm. The minimum conditions to be fulfilled are:

Limit of elasticity	30 kilos. per square millimetre.
Breaking strain	56 kilos. per square millimetre.
Extension measured after rupture	14 per cent.

Between two bars from the same hoop, a variation of six kilos. per square millimetre is allowed in the limit of elasticity, and seven kilos. in the breaking strain. The following table contains a certain number of results obtained at Terre Noire with cast-steel hoops made during the present year:

Nos.	Limit of Elasticity.	Breaking strain.	Extension.	Contraction.	No. of blows to produce rupture.	Deflection at 15th blow measured in mm.
1	39.4	66.0	16.6	0.74	24	31.0
2	39.0	65.5	16.8	0.72	29	31.8
3	41.8	67.5	15.6	0.715	29	31.4
4	40.3	66.7	14.9	0.66	29	31.6
5	36.1	61.7	17.9	0.55	29	32.8
6	39.3	66.3	15.4	0.70	36	31.0
7	37.2	63.6	18.3	0.56	34	32.0
8	38.5	65.2	17.3	0.64	35	32.0
9	38.0	64.8	20.1	0.52	45	31.8
10	40.0	66.7	17.6	0.55	42	31.0
11	38.9	65.1	18.1	0.54	41	31.7
12	39.3	65.9	17.3	0.54	36	31.6
13	40.8	68.0	13.2	0.68	45	31.0
14	39.8	65.6	18.0	0.55	47	31.5
15	38.3	64.5	17.2	0.53	36	33.0
16	37.5	63.1	16.1	0.68	28	32.5
17	37.4	62.6	14.9	0.64	26	33.0
18	38.5	64.2	14.4	0.72	27	36.0
19	37.9	63.0	16.7	0.52	42	?
20	36.0	56.6	24.2	0.50	25	40.0

Each of these figures represents the mean of two tests, in which the differences observed in the limit of elasticity and the breaking strain varied from 0.1 kilo. per square millimetre to 1.6 kilo. Tests Nos. 9, 10, 11, 12, are those of hoops which had been tempered three times in oil. No. 13 has a somewhat low extension but a high breaking strain. A charge is occasionally produced giving a breaking strain of 70 kilos. or more, and an extension of less than 13 per cent. In this case the series of hoops to which this tested hoop belongs are again heated and tempered in oil at a temperature lower than that at which

they were previously tempered. By this means the extension is considerably increased, without diminishing the breaking strain too much. On the other hand, when the breaking strain is too low and the extension high, the new tempering is effected at a higher temperature than the preceding one. In regular working, all the hoops are heated to a yellow oxidizing color, and at that temperature are plunged into a given weight of oil in the direction of their axes. They are allowed to cool in the oil, and are re-heated at a temperature varying from bright cherry-red to a dull cherry color, according to the chemical composition of the metal, and then tempered again in a bath of oil, in which they are allowed to cool.

The first tempering transforms the crystalline grain of the metal into a fine homogeneous grain ; the second determines the molecular equilibrium of the casting which corresponds to the chemical composition of the metal, and should be more or less intense, according as the metal contains more or less than 0.3 per cent of carbon and 0.5 per cent of manganese.

The chemical composition of the metal suitable for this delicate manufacture is comprised between narrow limits. The carbon varies from 0.28 per cent to 0.32 per cent, the manganese from 0.60 per cent to 0.45 per cent. The sulphur can scarcely be detected, and the silicon is nearly constant between 0.15 and 0.20 per cent.

Mr. Pourcel's paper called forth a discussion, a translation of which was published in "Notes on the Construction of Ordnance, No. 20," War Department, and from which the above was taken.

> "In general terms, as stated by Mr. Holley, the object of greatest importance in this process is to keep down oxidation in the bath from the commencement of the operation. For this purpose the furnace must be kept as hot as possible, with a good solid body of flame, but there must be only just enough air admitted to promote thorough combustion.
>
> The process requires an initial bath of pig-iron containing from 6 to 8 per cent of manganese. Spiegeleisen is the most convenient form for introducing it; but as a spiegel with precisely this percentage may not be at hand, the bath may be formed by taking a richer spiegel and diluting it with a proper proportion of ordinary pig containing no manganese. The greater part of the bath should be made of pig poor in carbon, particularly when highly carbonized materials are to be dissolved. The weight of the initial bath should generally be about 11 per cent of the whole.
>
> When the bath is completely melted, the refining materials are successively added in small quantities. These are preheated and dropped at the deepest part of the hearth in front of the doors. Pre-heating is employed not only to keep the

furnace hot, but to save oxidation. The materials used at this period of the operation are chosen with reference to the quality required in the finished product. For projectiles, the Terre Noire Company generally use Bessemer ingot and rail ends with sinking-heads from previous projectile charges. These are all high in carbon, and contain some manganese. The proportion of refining materials to the whole charge averages 78 per cent. As soon as one charge is melted, another is added, until all are fused, when a series of tests commences. The study of these specimen tests is kept up until the bath is in a condition to receive the final additions. These consist of a special pig (11 per cent of the whole charge) containing 4½ per cent of silicon and 3½ of manganese, and also a little ferro-manganese, containing 50 or 60 per cent of the latter. A part of these ingredients is taken up by reactions which prevent the formation of blow-holes; the remainder is left in the metal to impart to it the physical qualities required.

The special pig is charged hot. While it is melting, a marked change takes place in the bath, which up to that time has bubbled about as much as in the ordinary pig and scrap operation; it becomes gradually more and more quiet, until its surface is smooth and scarcely broken by small and widely-scattered bubbles. When the special pig is nearly all melted, the ferro-manganese is thrown in hot. The casting takes place immediately. The metal runs into the moulds without any splashing, and no escape of gas is noticed during the casting operation.

Spiegeleisen is used for the initial bath because the manganese it contains, being the most oxidizable of all the materials present, will remove oxygen that may be present in the bath, and will intercept oxygen that tends to enter it, so that the more manganese there is in the slag the less oxygen there will be in the metal below. By testing the slag frequently, there is constantly present a delicate test of the oxidation of the bath. If this precaution were not taken, and the oxygen were allowed to go on accumulating in the bath, it would be impossible to tell how much there is of it present when the final additions of silicon and manganese are made, and how much of these substances would be removed in taking up this oxygen. Therefore oxygen must be kept out, so that the

whole of the ingredients finally added shall be left to perform their work.

The success that has thus far attended the development of this manufacture indicates a useful and important future for the process.

The persevering efforts of the Terre Noire Company to develop this manufacture and the expense attending years of experiment, prove their confidence in the principle involved, and the encouragement given during the past two years by the Government shows an appreciation of its merit. Further experience may justify the use of the metal more generally in the construction of cannon, and, if it can be made hard enough for the purpose, it may be used for tubes. It will require exhaustive experiments to induce artillerists to accept in all cases the simply cast metal as a substitute for that forged under a hammer or press; but if a perfect demonstration shall be made of its ability to endure all tests, it will open a way to a great economy in manufacture.

PRESENT CONDITION OF FRENCH ARTILLERY.

The artillery of the army is under the control of the director of artillery in the war department. All guns for the field and for purposes of siege and position are fabricated under instructions from this office.

The list of guns under these heads, now actually in use, comprises a large number of models and varied constructions. This is the result of the hurried manner in which, before the end of the last war, guns of all available descriptions were collected by the Government. During late years, while the re-arming of the country has been progressing, a systematic method of armament has been adopted; but this has not, up to this time, so far advanced as to justify the exclusion of the old guns from the list of those in actual use. As the number of the new guns, however, shall increase they will be substituted for the old; consequently, in presenting the present condition of the artillery of the army, the old are alluded to only in a general way.

Omitting mention, then, of the bronze smooth-bore, and bronze and cast-iron rifled pieces of old date, the following may be stated as the present armament of the artillery of the army:

	Kilos.
80-millimetre (pièce de montagne), weighing	105
80-millimetre (pièce de campagne), weighing	425
90-millimetre, weighing	530
95-millimetre, weighing	710
120-millimetre (pièce de siége et position), weighing	1,200
155-millimetre (pièce de siége et position), weighing	2,527
190-millimetre (pièce de siége et position), weighing	8,000
240-millimetre, weighing	17,000
220-millimetre (steel rifled mortar).	
Revolving cannon (model of 1879), Hotchkiss.	

These guns, with the exception of the revolving cannon last named, are all constructed on the system of Colonel de Bange, late of the army. In addition to them, the army gun factories are employed in the manufacture of a large number of 24-centimetre guns, which have a cast-iron body tubed and hooped with steel (Plate LII.). They are made to assist in arming the coast. They are also much more economical than all-steel guns." *

Colonel Crispin, U. S. A., in his report, has given an interesting reference to the introduction and development of hooping cast-iron with steel bands or hoops :

It appears that the first attempt was made in 1836, at the founderies of Liege, in Belgium, where the minor powers of Europe, and even Russia, procured their cannon at that time ; resort being had, however, also to the well-known Swedish founderies of Fingspong and Aker.

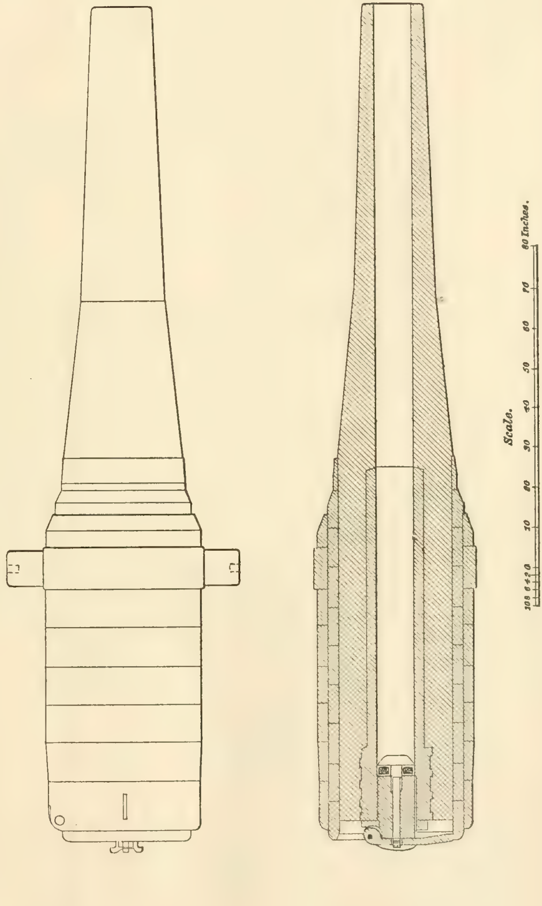
The method was first brought into notice at Ruelle, in 1843. It was introduced a few years later by Blakely, in England ; and in 1859 it was tested again in France, at Vincennes, by the Navy Department, and officially adopted for all its rifled guns. In 1864, in the model then adopted, the exact allowances for shrinkage were established, based upon both practical and theoretical observations.

The allowance for shrinkage, it is intended, shall be such as to secure a compression of the interior strata according to the theories of Gadolin and Lamés. The amount of diminution of diameter of tubes varies from 0.003 to 0.007 inch.

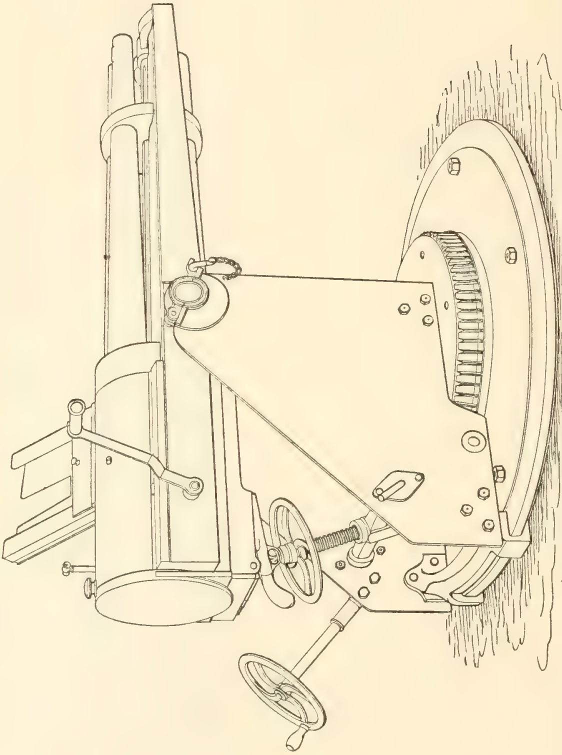
It is hardly necessary to allude to the fact that the large constructions for naval service have two series of puddled steel frettes, made at Le Creusot and Rive de Gier.

The banded portion of the cast-iron body is, according to general rules, about one caliber in thickness, and the bands 0.25 caliber for each row, giving a thickness at the seat of dangerous pressures of about one and one-half calibers.

* Gun Foundry Board Report.



24-CENT. B. L. R. MODEL OF 1876--ARMY.



HOTCHKISS 53 Mm. REVOLVING CANNON AND NAVY CARRIAGE.

The operation of shrinking on the hoops requires but simple and ordinary appliances. An oven, modeled after the ones employed in England for heating tires for wheels, supplies the means for heating the frettes to the proper temperatures. They are transferred thence by means of a small crane, and are placed in their proper positions on the exterior of the prepared cannon body by two or three workmen. A circular tube and collar containing water, which escapes in jets on to the superimposed frette, supplies the means for cooling. It is applied, not directly after the placing of the frette in position, but in about ten minutes after the latter operation has been completed.

After preparing the body, and the assemblage of the first row of bands, the gun is transferred to the boring-lathe, the exterior of the frettes accurately turned, and the preparations for the application of the second row of bands completed. After this row has been superimposed, the gun is sent to the machine-shop for the final process of fitting the fermeture, rifling, and other necessary work to complete the manufacture.

Proof-frettes are tested for elasticity, and proof of endurance by a shrinkage test. A cast-iron cylinder is used, over which the experimental hoops are placed under a definite tension of heat, and when the parts are cut, the cylinders are broken up and the frettes under proof measured and otherwise examined. A shrinkage determined upon, say, nearly up to 0.002 of the diameter, and a slightly less one for trunnion-bands, should attain without any permanent set resulting in enlargement. They should withstand an enlargement not exceeding 0.004 without rupture, or development of serious superficial defects sufficient to warrant rejection. Based upon these trials, the frettes are prepared which are to be used in construction.

In the application of frettes or trunnion-bands to the bodies of guns, the establishment of the limits of shrinkage must largely depend upon the results of the testing machine for physical properties, and limits which may be determined by one set of experiments may be non-concurred in by another, operating on different metals used in different countries. The data resulting from French experiments are, therefore, matters of interest, but furnish no definite standard for following absolutely when other steels are used.

> "The ordnance of the navy is attached to a department in the ministry of marine, called the 'Direction of Material.' The bureau of the artillery of the navy is one of several bureaus under this 'Direction,' and is presided over by an officer, 'chargé du service technique,' who is virtually the chief of naval artillery. This position is filled at present by General Dard, an officer of great eminence in the marine artillery of France.
>
> The list of guns of the marine artillery comprises a large number of calibers; and the variety in their construction shows the growth and development of the idea which has finally resulted in an armament for the navy of guns constructed en-

tirely of steel, including the following calibers, viz., 65 and 90 millimetres, 14, 16, 19, 24, 27, 32, 34, 37, and 42 centimetres. The Hotchkiss revolving cannon (Plate LIII.) also forms an important element in this armament." *

Mr. Hotchkiss has recently perfected some rapid-firing guns, of which a great number are being introduced into the service. Their object is to provide a suitable armament for torpedo-boats, and to meet the demand for a rapid-firing gun of small caliber.

Though high-power guns of this system (see table facing page 737) are supplied with other ammunition, the same ballistic conditions as those for the revolving cannon have been adopted for the 37, 47, and 53 mm. guns, in order to meet the important advantage of having uniform ammunition.

The body A (Plate LIV.) of gun is made of Whitworth fluid-compressed steel. It is square at the breech, and the trunnion-ring B (steel) is screwed on. The gun is exactly balanced in the trunnions.

The breech-action consists of the square wedge C, running in guides D, and governed by a set screw. It is worked by a crank E, bearing in the right side of the breech, and is actuated by the lever-handle F.

The firing mechanism consists of a hammer with a point that penetrates the firing-plate, and strikes the cartridge-cap on pulling the trigger. The hammer is mounted on a rocking-shaft, and is provided with an arm on the outside of the breech. The lever-handle carries a cocking-cam, which bears on the arm of the rocking-shaft, and in swinging, cocks the piece. A small projection and trigger-sear hold the hammer until it is released by pulling the trigger. The parts are all simple, and a hinged piece can be readily opened to replace any broken part.

The cartridge-extractor is a prism of steel with a hook running in a recess on the interior of the left cheek of the breech, and parallel to the bore. On its under side is a stud, working in a groove on the left side of the wedge. The stud runs in the straight portion of the groove until the wedge is so far withdrawn that the opening coincides with the chamber, when it runs into the inclined part. By this action, the extractor is thrown back quickly, withdrawing the cartridge-case and dropping it to the ground.

The stock G is of wood, fitted into a gun-metal holder. An india-rubber tube is attached to it, forming an elastic buffer, and reducing the effect of the slight shock of discharge.

The pistol-grip H is of gun-metal, hollow, and attached to the breech by screws. This carries the trigger I, and serves at the same time to direct the piece with the right hand, leaving the left free to feed the cartridges.

The front sight N is a plain steel point attached to the trunnion-ring. The rear sight O is a folding leaf or sliding bar with the usual notches, so that the gunner may pass rapidly from one range to another.

* Gun Foundry Board Report.

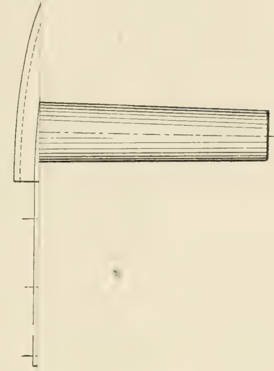
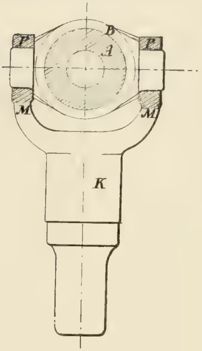
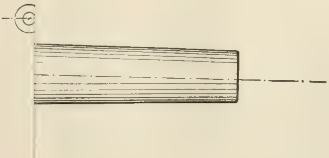


Fig: 3.
Section through Trunnions.



Scale.



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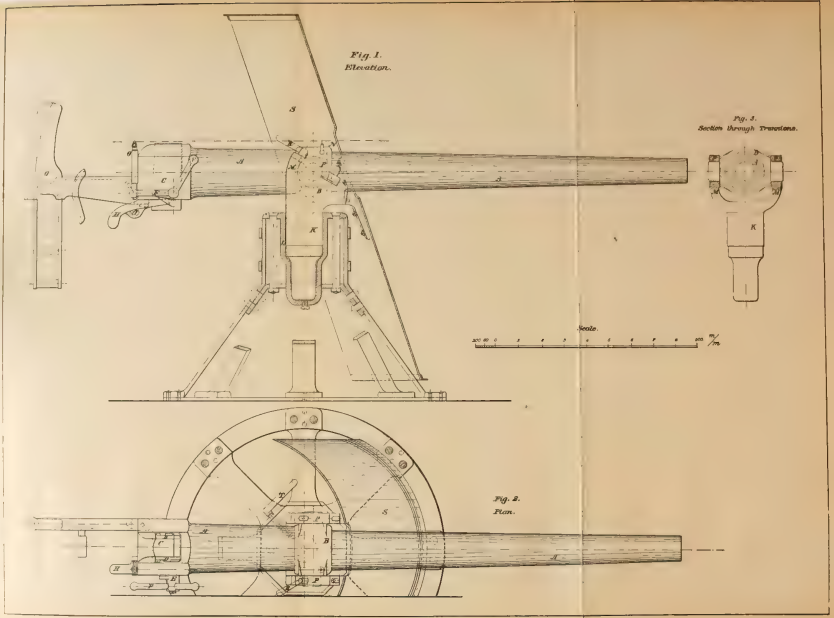

HOTCHKISS 57 Mm. RAPID FIRING GUN.

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The pivot K, and socket L, are of gun-metal, and made to suit the conditions of the tower, or other part of the vessel or place in which the piece is to be mounted. The pivot carries the gun in its trunnion-bearings M, and fits in the socket so that it rotates and forms a universal joint, thus providing for both vertical and lateral train.

P are the cap-squares clamped by the lever R. T is a lever for clamping the pivot in its socket when no rotation is desired. S is a steel shield to protect the gunner. It is fixed to the gun and revolves with it.

The following recoil-buffers have been found useful. The trunnion-bearings are bored larger than the diameter of the trunnions, and the circular space between the two is filled with soft india-rubber, wholly enclosed in flanged rings, that fit over the trunnions and in the trunnion-bearings. The sharp shock on the bearings is greatly reduced without inconvenience to the gunner.

In the 37 mm. gun, there are 12 uniform grooves, 0.4 mm. deep and 2 mm. wide. The rifling is helicoidal, left-hand twist, with a pitch (in calibers) of 29.9, and an angle of 6°.

To load and fire :

1st. Throw down the lever-handle, pressing with the right thumb.

2d. Insert the cartridge with the left hand.

3d. Return the lever to place (with palm of the hand). This raises the block to its proper position, and the gun is ready to fire.

After firing, throw down the lever sharply, and the empty cartridge-case is thrown out of the gun.

> "Many of the guns of the Marine Artillery, including some of 32 centimetres, are models of previous years—cast-iron bodies hooped with steel; cast-iron bodies with half tubes of steel and hooped (Plate LV.); cast-iron bodies with steel tube extending the whole length of the bore and hooped with steel —all indicating the persistent effort that has been heretofore made to utilize cast-iron. The other guns mentioned above are entirely of steel.
>
> The Marine Artillery is engaged in the construction of a modification of the 27-centimetre and 32-centimetre guns of model 1870, to be called the model of 1870–81. They are to be of cast-iron, tubed and hooped with steel; their length will be increased to fire heavier charges than the model 1870, giving a velocity of 530 metres; eight 27-centimetre and twenty-six 32-centimetre guns of this pattern are under construction."*

Colonel Sebert, referring, in 1873, to the introduction of steel tubes, gave the following description of the model of 1870:

* Gun Foundry Board Report.

HOTCHKISS SINGLE-BARREL, RAPID-FIRING, NON-RECOIL GUNS.

The High Power Guns are usually mounted on a stand, bolted to the deck. The sockets for the other guns are bolted to the hand rails, or any other convenient part for the ship.	These Guns use the ammunition of the revolving cannon of same caliber			High-Power Guns			
Caliber	37 mm	47 mm.	53 mm.	37 mm.	47 mm. (a)	47 mm. (b)	57 mm
Length of bore	740 mm.	1175 mm.	1272 mm.	1406 mm.	1786 mm.	1880 mm.	228[illegible]
Length of bore in calibers	20	25	24	38	38	40	[illegible]
Length of gun	840 mm.	1325 mm.	1605 mm.	1506 mm.	1954 mm	2048 mm.	2515 mm
Length of gun, including stock or shoulder piece	1140 mm	1825 mm.	2125 mm.	2020 mm.	2500 mm.	2600 mm	[illegible] mm
Weight of gun, including stock or shoulder piece	35 kilos.	100 kilos	156 kilos.	120 kilos.	180 kilos.	230 kilos.	[illegible] kilos
Weight of pivot	17 kilos.	35 kilos	56 kilos.	50 kilos.	56 kilos.	60 kilos.	[illegible] kilos
Weight of socket	10 kilos.	10 kilos	60 kilos.	250 kilos.	250 kilos.	300 kilos.	[illegible] kilos
Weight of steel shell	512 gr	1075 gr	1700 gr.	800 gr.	1500 gr.	1500 gr	[illegible] gr
Bursting charge	15 gr.	15 gr	60 gr	30 gr	60 gr.	60 gr	115 gr
Length of steel shell, in calibers	2.57	2.5	3	4	3.66	3.66	3.58
Charge of powder	80 gr	220 gr.	410 gr.	320 gr.	500 gr.	750 gr	[illegible] gr
Total length of cartridge with projectile	167 mm.	234 mm.	310 mm.	370 mm.	395 mm	515 mm.	477 mm
Total weight of complete cartridge	685 gr	1535 gr	2390 gr.	1420 gr.	2400 gr	2780 gr	[illegible] gr
Initial velocity of projectile	402 met.	450 met	430 met.	600 met.	500 met	600 met.	[illegible] met
Total muzzle energy of projectile, in kilogrammetres	4217	11,100	17,548	18,482	19,116	27,527	41,914
Thickness of iron plate that the projectile will penetrate	30 mm.	50 mm.	65 mm.		80 mm.	120 mm.	
Rapidity of fire, per minute, careful sighting not included	[illegible]	20	20	2[illegible]	20	15	15
Number of men required to work the gun	1	2	[illegible]	2	2	2	2

The pivot K, and socket L, are of gun-metal, and made to suit the conditions of the tower, or other part of the vessel or place in which the piece is to be mounted. The pivot carries the gun in its trunnion-bearings M, and fits in the socket so that it rotates and forms a universal joint, thus providing for both vertical and lateral train.

P are the cap-squares clamped by the lever R. T is a lever for clamping the pivot in its socket when no rotation is desired. S is a steel shield to protect the gunner. It is fixed to the gun and revolves with it.

The following recoil-buffers have been found useful. The trunnion-bearings are bored larger than the diameter of the trunnions, and the circular space between the two is filled with soft india-rubber, wholly enclosed in flanged rings, that fit over the trunnions and in the trunnion-bearings. The sharp shock on the bearings is greatly reduced without inconvenience to the gunner.

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> "Many of the guns of the Marine Artillery, including some of 32 centimetres, are models of previous years—cast-iron bodies hooped with steel; cast-iron bodies with half tubes of steel and hooped (Plate LV.); cast-iron bodies with steel tube extending the whole length of the bore and hooped with steel—all indicating the persistent effort that has been heretofore made to utilize cast-iron. The other guns mentioned above are entirely of steel.
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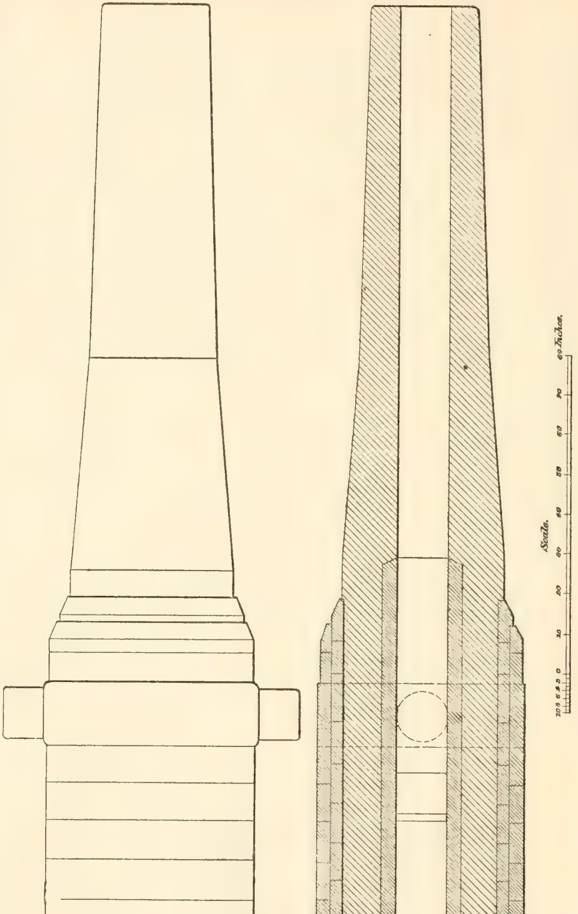
* Gun Foundry Board Report.

PLATE LV.



32-CENT. B. L. R.—MODEL OF 1870.—NAVY.

The soft steel tube, tempered in oil, is prolonged to a little in rear of the trunnions, where the gas exerts but feeble pressure. It is reinforced in rear, and this reinforced part, designed to receive the breech-plug, is itself screwed into the casing.

The thread of the screw designed to secure the tube was one of the points which demanded most study and gave the greatest difficulty ; a form was finally determined, so arranged as to secure solidity to the system.

The tube, with its diameter larger than that of its casing by a slight amount determined by calculation, was inserted into the gun, which was in a vertical position, and heated to a low temperature in order to give it just sufficient expansion. * * * The tube having been inserted until the shoulder of its reinforced part rests against the plane of the breech, is given a rapid motion of rotation, which screws it in, and forces the front of it firmly against the bevel connecting the bore of the casing with the counter-bore.

By this process, the tube is compressed in the part comprised between the front bevel and its shoulder held by the screw-thread. This compression arises from the cooling and shrinking of the gun, and, inversely, the gun is subjected over the same length to a longitudinal extension.

This double condition appears to be essential to the success of tubage. I will not stop to explain the considerations which enabled them to ascertain this fact; it suffices to say that the amount of longitudinal shrinkage, for each caliber, is exactly determined by calculation, the same as the diametrical shrinkage of the tube. The gun, once it has been tubed, ordinarily receives an exterior frettage.

Numerous experiments have shown the success of this system. By experiments with various calibers, and by the final employment of excessive charges and violent powders, the manner of destruction of these guns has been examined. It has been thus shown that the object desired has been fully attained, that is to say, that the resistance to the blowing out of the breech now predominates over the resistance of guns to transverse rupture, and that consequently at the limit of the life of the gun, and supposing the use of ordinary service charges, rupture announces itself by cracks of the inner tube, which thus prevents all danger of premature explosion.

It may be interesting to know the increase of resistance which frettes and tubes together give to the naval guns. The following are the results on the subject, determined by calculation. These data are taken from the memoir of Colonel Virgile ; they apply equally to all our guns, which have the same thickness, one and a-half calibers :

1st. Guns of Ruelle, cast-iron, without either frettes or tubes, the cast-iron standing 11,257 pounds per square inch, offer a resistance of 10,000 pounds per square inch.

2d. Similar guns with a single row of frettes, the cast-iron standing 11,257 pounds per square inch, and the puddled steel, 35,600 pounds, have a resistance of 20,000 pounds.

3d. Guns with two layers of frettes, for a mean tenacity of the casing and frettes, reached 28,700 pounds.

4th. The same guns with tubes reach 45,900 pounds. The addition of frettes and tubes more than quadruplicates the original strength of the cast-iron guns.

"The 37-centimetre and 42-centimetre guns were in hand when General Dard came into his present office, and will be completed. Their weights, respectively, are 72 and 75 tons, and their construction is the same.

Eight 42-centimetre guns are in process of construction, assigned to the following turreted ships, viz., Indomptable, Requin, Terrible, Caiman.

One gun weighing 100 tons has been built by the marine artillery at Ruelle, but it is of 42-centimetre caliber, with the same sized tube as that in the 75-ton gun. It is, in fact, the 42-centimetre gun, with a body of cast-iron instead of steel. Being constructed for the purpose of deciding all the ballistic particulars of the 75-ton gun, cast-iron was employed for economic considerations.

The following are accepted by the bureau of marine artillery for the future armaments of the navy, and will be entirely of steel, viz.:

	Length in calibers.
65-millimetre	
90-millimetre	
10-centimetre	
14-centimetre shell-gun	30
16-centimetre (light), with one row of hoops	28½
16-centimetre (heavy), with two rows of hoops	28½
24-centimetre	28½
27-centimetre	28½
34-centimetre, 44 tons weight	18
34-centimetre, 48 tons weight	21
34-centimetre, 49 tons weight	25
34-centimetre, 52½ tons weight	28½

Material.—Although the gun factories of the army and marine artillery are engaged in the fabrication of guns with cast-iron bodies, and though Colonel de Bange advocates puddled steel for hoops, the effort to perpetuate the use of cast iron is now definitely abandoned as far as the navy is concerned, and the employment of forged cast-steel will be generally accepted."*

While nearly all authorities in France are in favor of tempering, there are still diverse opinions as to its hardening effect, and as to the best system to be employed in the operation.

* Gun Foundry Board Report.

Mr. Harmet, chief engineer of the steel works of St. Étienne, argues that the usual method of plunging the tubes entirely in oil, which causes the cooling to begin simultaneously on the outer and inner surfaces, creates three different zones of cooling in the thickness of the metal, the central one of which begins to contract only when the two outer ones are already set. The tensions of the metal consequently vary towards a line in the middle of its thickness, instead of being concentric with the axis of the tube. Mr. Harmet proposes to attain this latter result by filling the tube with water and applying none to the exterior.

In regard to tempering, Colonel Crispin concludes, as the result of his recent investigations of the subject in Europe:

The effects of oil-tempering are to increase the hardness, tensile strength, and elastic limit of the metal, but somewhat at the expense of its ductility. It is a process, however, which is applied to all steel products for heavy ordnance in England, and also in France, and has been so long practiced, with confidence in it remaining so long unshaken, and, in fact, increasing, that it must be recognized as probably an important process to be employed in constructions where steel tubes of about equal diameters throughout their entire length are designed for use in built-up guns. For ingots, however, wherein unequal diameters find place, the process becomes one of doubtful benefit in its application, as it evidently disturbs the molecular conditions of the metal; sections of different diameters being unequally acted upon by the tempering process, injurious strains are introduced similar to those produced by unequal cooling in masses of cast-iron, where the areas of adjacent cross-sections are sensibly and abruptly different.

The increased hardness and diminution of the percentage of elongation in the metal introduced by the application of the process are subjects for consideration, and should leave the question of tempering, in my judgment, one for consideration and further experiment.

The increased tenacity and hardness secured by the process was a matter of great moment to the English constructors when the Palliser stud system of projectiles was standard in the British service, as the enormous strains brought to bear on the bearing edges of a few deep rifle grooves required these qualities to be present in the highest degree attainable; but now, when the Palliser stud system for securing rotation is a thing of the past, it remains to be considered if the merits of the oil-tempering process should not be further inquired into, both theoretically and experimentally, if practicable, and the result may be that a modification of the process, securing an increase in toughness and tenacity to a more limited extent, may be attained without sacrificing too much the extensibility of the metal, which, by permitting a *yielding* at the critical period in gun practice with high pressures, instantaneously produced, adds largely to the ability of the construction to withstand the effects of those powerful, dangerous, and suddenly applied strains.

The steels used have not changed in qualities since 1872, and about the same physical properties obtain now as then, as exhibited by their tests. A soft steel of about 31 tons per square inch at the breaking point, and when tempered in oil raising to 47 tons, is now, from the latest information in print, about the standard required at the Woolwich arsenal. The untempered steel reaches its elastic limit at, say, 13 tons per square inch, and the tempered at 31 tons per square inch. It is thus apparent that the oil-tempering not only increases the tensile strength of the metal, but also increases in a much greater ratio its elasticity.

It is stated on good authority that no standard of heat required for tempering has been established—different specimens requiring different heats—and hence tests for the required temperatures are made for each tube from specimens taken from their ends. The more hammered steels require less heating than the less denser or softer ones, and hence the degree of heat required varies in every case, depending on the grade of the steel under treatment as to its physical properties as determined by tests.

"**Construction.**—The army guns are fabricated on the system of Colonel de Bange. This construction requires an oil-tempered and annealed steel tube, with hoops shrunk on in such numbers and in as many layers as are necessary to resist the strain brought on them by the charge. The hoops are made of puddled steel, coiled and welded. This construction is carried to the 240-millimetre gun (Plates LVI., LVII.), of which there are very few in the service.

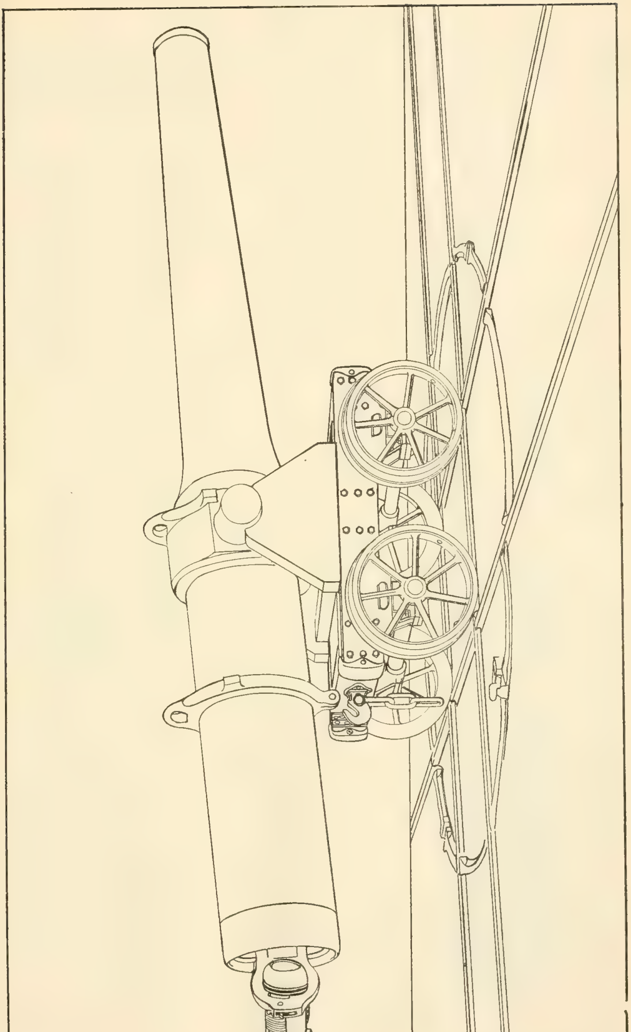
There is a serious effort on the part of the officers of the artillery to introduce a change in the method of construction, so as to have the hoops made of forged steel, and it is thought that this may result in introducing a modification so far as to have the rear hoop, in which the breech-mechanism is seated, and the trunnion hoop made of forged steel, while the coiled puddled steel will be retained for the other parts.

There are two constructions of the 34-centimetre gun of 21 calibers; one has a thick tube, with two rows of hoops; in the other, a thin tube is covered its entire length with a jacket of the same thickness as the tube, and two tiers of hoops. These guns are intended to give an initial velocity of 600 metres.

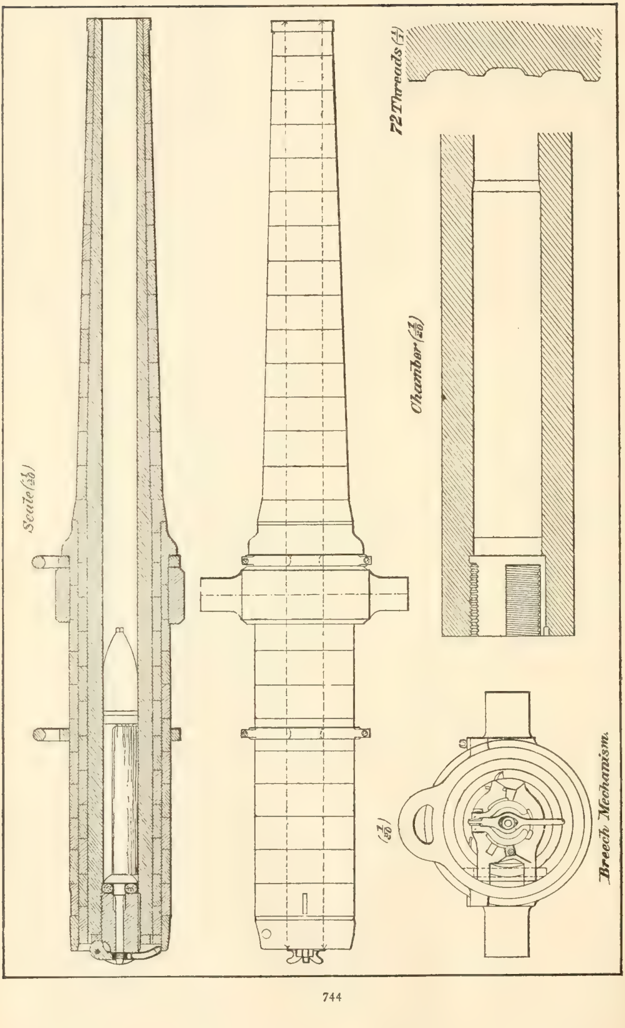
General Dard is experimenting in the direction of a larger caliber, and has under construction a gun of 37 centimetres, of the following dimensions, viz.:

Diameter of bore......................................centimetres....	37
Diameter of chamber......................................millimetres....	385
Thickness of tube..do......	140

PLATE LVI.



DEBANGE 240 Mm. B. L. R.


Scale (1/20)
72 Threads (1/1)
Chamber (1/20)
(1/20)
Breech Mechanism.
DE BANGE 240 Mm. B. L. R.

Thickness of jacket........................millimetres	142.5
Thickness of hoops (1st row).......................do......	107.5
Thickness of hoops (2d row).......................do......	132.5
Total diameter.......................do......	1,430
Total length.......................do......	11,185
Length of bore.......................do......	10,545
Length of breech-mechanism.......................do......	640
Weight of gun.......................tons...	72
Weight of tube.......................do......	14.7
Weight of jacket.......................do......	16.4
Weight of ingot for tube.......................do......	20

This gun is entirely of steel, and the tube is in one piece. From its great length it is evident that a large charge of powder can be consumed in it, but the proposed weight of charge and projectile is not known.

The construction of the 37 and 42-centimetre guns (Plate LVIII.), consists of an inner tube in one piece, on the rear end of which is screwed a short tube accommodating the breech mechanism. The tube is enveloped in a jacket, composed of two pieces hooked together forward of the trunnions and inclosed by two layers of hoops." *

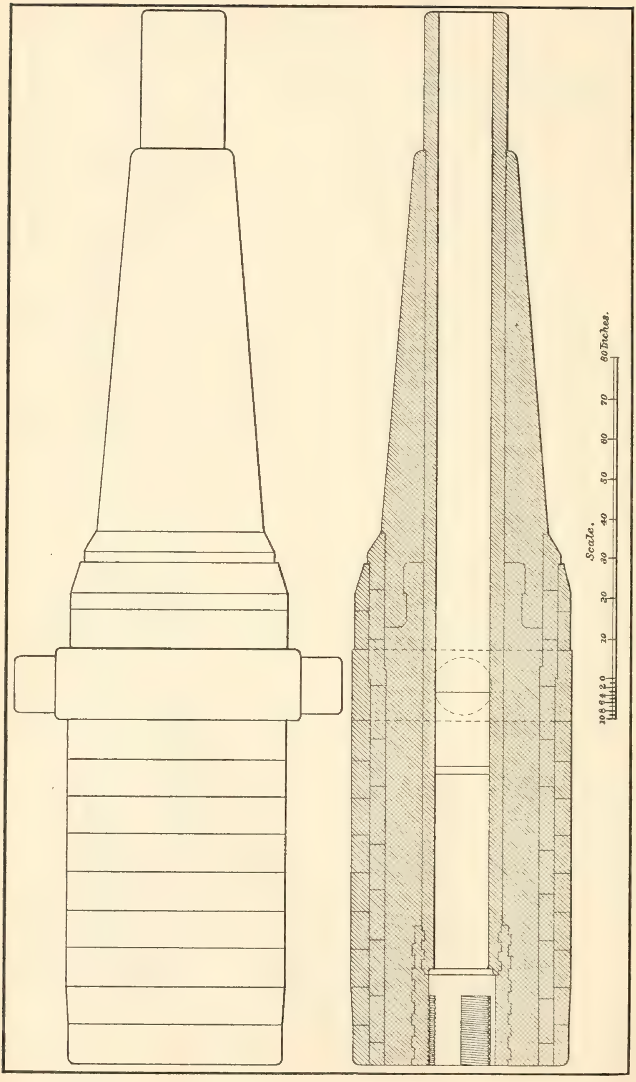
Of this construction Colonel Crispin has written :

The original model was designed, generally, after its prototype of 1870, to which it is a natural sequence growing out of the experiences of ten years of test and manufacture of the latter, aided by the developments and advancements resulting from the rapid strides in France and England in the production of steel.

Its salient features are a steel, oil-tempered tube (*held simply by shrinkage*), placed in a steel body consisting of two parts of about equal weight, united by locking together, the whole strengthened by two rows of shrunk-on frettes, superimposed over the body. The fermeture placed in the rear section of the body has no connection with the interior tube. This construction generally gives all the advantages to be derived from the use of the strongest and most suitable metal for ordnance ; is built up in accordance with the theories of construction for tangential strength, as far as they can practically and with due regard to economy be applied ; and by the separation of the inner tube from the body ; disconnecting the end strain from the tangential at this point introduces a feature constituting a true and important departure from the ordinary mode of construction now in vogue. The *failure*, however, *to lock* the tube to the body—to prevent the forward thrust of the former, arising from the friction of the moving projectile, and the gases operating on the shoulder of the chamber—save by the friction between the tube and body—is a *radical* defect,

* Gun Foundry Board Report.

PLATE LVIII.



SYSTEM OF CONSTRUCTION OF 37 AND 42 CENT. B L. STEEL RIFLES.

and *experience* has developed it and led to a modified form of construction. This modification consists of a hollow cylinder screwed into the casing, and with sufficient length to afford a rest for the fermeture, and to afford a means of being locked to the interior tube. This, of course, will prevent the tendency of the tube to move to the front; and it was this cause, it appears from recent French authorities, that led to the modifications just noted.

In this modification, the junction of the inner tube and body takes place practically at a point equivalent to the bottom of bore in muzzle-loading guns; and as the phenomena in the act of firing in a breech-loading or muzzle-loading gun—the breech-loading gun using a French fermeture—are essentially the same, it is believed that all the disadvantages arising from having to contend with the union of the *two* strains at the bottom of the bore still obtain in this construction. Therefore the union as proposed in my report seems to me to be preferable.

In this connection, attention again may be invited to the practical experience had both here and in England of the power of the drawing forces exercised on the *surface of the bore* by the friction arising from the passing projectile and the powder-gases. The gases operating on the bottom of a closed tube, as a *point d'appui*, hold it from any forward movement, and the grip of the projectile from friction tends forcibly to drag the *metal immediately around the surface of the bore* to the front, elongating it, and leads to a longitudinal rupture commencing at the surface, and finally extending through the thick tube, as in the case of the Duilio gun, or in the case of a lining-tube with a bottom, of forcibly rupturing it, and dragging it out of the body of the gun, and projecting it to the front, as in the case of the English and American guns which have been so disabled. No such phenomena can occur if the inner tube is bottomless and firmly secured to the superimposed body.

The absolute separation, however, of the longitudinal and tangential strains by designs in construction which shall contemplate entirely different parts of the system to separately withstand these stresses, is now one of the most prominent ideas which is engaging the attention of the ordnance constructors of the day.

The first inventor to believe that an advantage might be gained by the complete separation in a gun construction, *united in all its parts*, of the tangential and longitudinal strains at the breech was, as far as I can judge, Captain Emile Schultz, of the French artillery, who, as far back as 1875, shows in one of his illustrations of a wire gun, a design giving a practical application of this idea.

> "The above presents, in a condensed form, the present condition of construction in France. Particulars of most of these guns are published and can be referred to at pleasure. The only new guns to be developed are those of General Dard and Colonel de Bange, both of whom propose a 34-centimetre gun. Some particulars of the Dard gun have been given above.
>
> The de Bange gun is made up of an interior tube and three rows of hoops, and the following are some of the particulars:

Caliber ....centimetres...	34
Weight..tons...	37
Charge of powder ....kilogrammes...	180
Weight of projectile ....do......	450
Calculated velocity ....metres...	610
Outside diameter at breech...millimetres...	940
Rows of hoops at breech...do......	3
Rows of hoops at muzzle...do......	3
Energy expected to be developed per ton of gun......metre-tons...	230
Weight of carriage...tons...	24
Weight of slide...do...	30

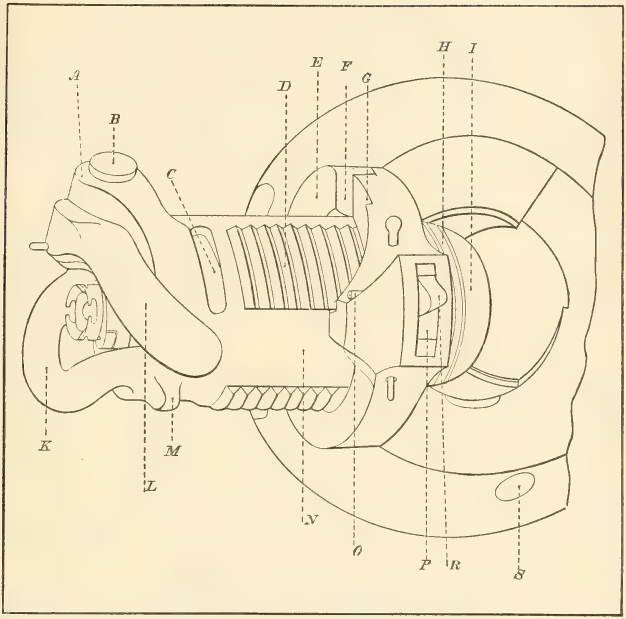
The high velocity and great energy claimed are said to be due to some peculiarity of the cartridge. The novel feature, however, in the gun lies in the manner in which it is proposed to insure longitudinal strength by the grip of the hoops on the tube and on each other. The outer surface of the tube presents a series of conical undulations; the interior surface of the first row of hoops corresponds with the form of that portion of the tube which they envelop, and a similar form is carried to the exterior of the hoop, thus continuing the same adjustment of parts to the third layer, the outer surfaces of which are shaped to suit the ordinary form of a gun.

In this system each layer is made to break joint with that below and above it. The inventor is erecting a special tool of his own invention, said to be capable of such modifications as will enable it to perform all the operations of boring, turning, slotting, rifling, &c., for which in ordinary manufacture several tools are required. The developments from this experiment may prove very instructive, and will certainly be very interesting.

Breech Fermeture.—All the French guns are breech-loading, and are fitted with the interrupted screw system as modified by Colonel de Bange to suit his gas-check." *

The French fermeture or breech-mechanism comprises the breech screw, the tray, the movable head, and the gas-check.

* Gun Foundry Board Report.



FRENCH BREECH FERMETURE.

A, Lug of the breech-block.
B, Lever-bolt.
C, Notch for latch-butt.
D, Screwed sector.
E, Support for the cam of the lever handle.
F, Safety slot.
G, Abutment of tray.
H, Gas-check.
I, Mushroom movable head.
K, Fixed handle.
L, Lever-handle.
M, Butt of breech-block.
N, Smooth sector or guide.
O, Latch-bolt.
P, Latch recess.
R, Latch.
S, Spring to release lever-handle.

All the parts of the breech-mechanism are assembled by pins, kept in place by friction.

By this means the entire mechanism can be easily taken to pieces. Moreover, if any of the pins are lost, they can be readily replaced, on account of their simple form.

When the breech is closed, the screwed sectors of the breech-block engage the screwed sectors in the breech. In this position the head of the lever-

handle L enters the safety-slot F of the tray and prevents any rotary motion of the screw during fire.

To open the breech, disengage the lever-handle from the safety-slot F, and turn the breech-block until its movement is stopped. In this position, the screwed sectors of the block face the smooth sectors of the breech, and the breech-block can be withdrawn. When the screw is turned, the butt of the latch is pushed by a projection, its upper nib being raised, and its lower engaging in its recess. At the end of this movement the tray is secured to the breech-hoop, and the latch is freed from the breech-block.

In disengaging the lever, its cam bears against the tray, and starts the gas-check from its seat, facilitating the withdrawal of the breech-block by hand. During this last movement, limited by a key-bolt, the breech-block is held and directed by the guides, the butt of the latch bearing against the body of the screw, keeping the lower nib in its recess. At the end of the movement, the block being withdrawn to its full limit, the latch is released and the tray swings on its hinge, throwing open the breech.

To close the breech, the tray is swung into its place and the breech-block thrust forward until its screwed sectors are opposite those of the breech. The screw is then turned, and if the breech is well closed, the lever-handle will fall by its own weight and engage in the safety-slot.

For the heavy calibers, the breech-block is fitted with a double handle to facilitate the operations of closing and opening.

The *fermeture* de Bange (Plate LIX.) is composed of an interrupted screw-block similar to the one just described. In its axis is inserted the stem D, figure 4, of the movable head K, shaped like a mushroom. Between this head and the face of the block is placed the gas-check M, or *obturateur*, as it is called.

> "**Gas-Check.**—The de Bange gas-check is universally employed, the tête-mobile of which is made of crucible steel supplied by Thomas Firth & Sons, of Sheffield, England."*

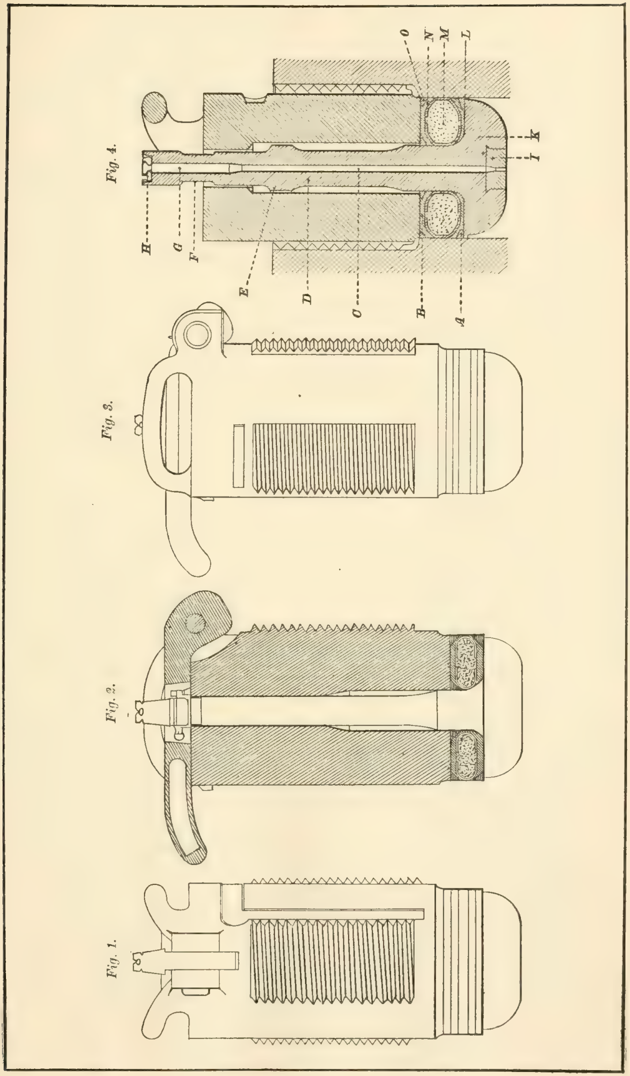
It is a linen collar filled with a mixture of 65 per cent of asbestos and 35 per cent of mutton suet, and fits snugly around the stem of the movable head.

The asbestos, being a mineral and not combustible, retains the suet and prevents the mixture becoming fluid. The suet being soft and greasy, yields easily to pressure and takes the form of its casing. It also oozes through the linen, lubricating the sides of the piece, without injuring them.

The collar is encased and protected with zinc rings, B, N, which maintain the form of the plastic material. Copper rings, O, are placed between the edges of the zinc rings and the breech-block on the one side, and other rings, A, between the zinc rings and the mushroom head on the other. They do not go entirely around the head, but are split open for a few millimetres, and are fitted to the gas-check to prevent the zinc entering the joints and jambing the fermeture.

When the gun is fired, the pressure upon the movable head is transmitted to the gas-check, which is forced against the sides of the chamber, causing perfect

* Gun Foundry Board Report.



FERMETURE DEBANGE.

obturation. C is the vent, entering the vent-bush I; E is a shoulder and F a neck on the stem; G is the place into which the primer is inserted; H, a notch for securing the outer end of the stem; and L, a fillet on one face of the mushroom.

One of the great advantages of this system of obturation is that the gas-check does not require a greater diameter than that of the bore. It is also cheap, easily fitted, and requires no seat. On the other hand, there are disadvantages that prevented, for a time, its adoption in the French Navy. Among them are the breaking of the stem, the fusion of the plastic material, and the absence of any means to prevent the escape of gas through the vent.

In the short 155-millimetre gun, a double gas-check has been fitted, one within the other. At the moment of firing, the pressure on the movable head is transmitted to the two gas-checks; the interior applies its power to the vent-bush, while the exterior exercises its pressure, in the usual manner, upon the sides of the chamber.

Chamber.—The powder chamber is cylindrical, and its diameter considerably greater than that of the cartridge.

> "**Rifling.**—The rifling is polygroove and parabolic in development."*

The number of grooves is not governed by any fixed rule, but is generally three times the caliber expressed in centimetres. For example, the 80-millimetre gun has 24, and the 27-centimetre, 54. The twist is from left to right and increasing.

> "**Rotating Rings.**—A single rotating ring of copper is used for all calibers. Its exact position has been determined by extensive series of experiments.
>
> **Wire Construction.**—The exponent of the system of wire-wrapping for cannon in France is the Schultz gun. A 34-centimetre gun made on the plan of Captain Schultz was built up as follows: A steel tube, figure 3 (Plate LX.), was wrapped circumferentially with steel wire and enclosed in a wrought-iron jacket; the longitudinal strain and the effort to blow out the breech was resisted by twelve longitudinal bars of steel set up at as equal a tension as possible between two bands shrunk on over the jacket, the forward carrying the trunnions and the rear inclosing the breech-mechanism, figures 1, 2. The gun was made at the works of the Compagnie de Fives-Lille in 1882, under the supervision of Captain

* Gun Foundry Board Report.

PLATE LX.

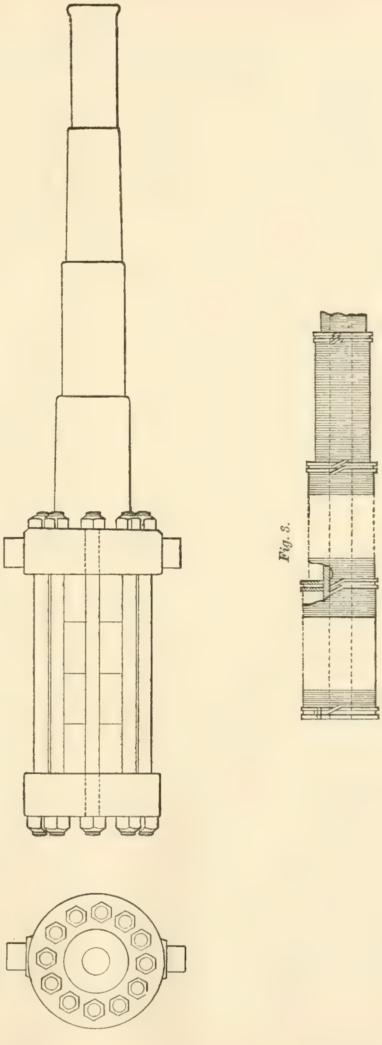


Fig. 1.

Fig. 2.

Fig. 3.

SCHULTZ WIRE GUN.

Schultz, and was sent to Gâvre to be fired. Owing to the unequal tension of the longitudinal bars, the gun failed at the first fire, February, 1883. The cause of the failure can be thus distinctly asserted, as the sound of the *successive* ruptures of the bars was recognized by those who assisted at the experiment. The charge was 242 pounds. The service charge was to be 264.5 pounds. Weight of projectile, 904 pounds. Six bolts gave way. Pressure in gun, 12.8 tons per square inch.

Previous to its trial, and in anticipation of success, four cast-iron guns of 24 centimetres were sent to Fives-Lille to be converted on the same principle. They are tubed with steel as far as the trunnions, and are wrapped with wire. The longitudinal bars are yet to be adjusted, after which they will be subjected to trial, with but faint hopes of success, as the failure of the original gun seems to have indicated very positively the mechanical impossibility of securing an equal strain on the longitudinal bars. The contract, however, having been made for the conversion of the four guns above named, it will be carried on to its completion."*

The *Revue Maritime et Coloniale* of August, 1881, has published the following relating to the system :

A process of fabrication which we will readily term "the process of the future," because it surely admits of conciliating relative lightness with great resistance, and therefore with great power, is the *steel-wire system*. Captain Schultz is the convinced advocate of this system in France, the decided advantages of which were long ago demonstrated in England, both theoretically and practically, by the civil-engineer Longridge.

These advantages were not lost sight of by the Navy Department, and to prove, in all their bearings, the merits of the system, two cannon, one of 10 cm. (3.94 inches), and the other of 34 cm. (13.39 inches), have been placed under fabrication in the works of Fives-Lille.

The principle involved in their construction may be summarized as follows :

1st. Division of the cannon into two parts, each of which is designed to resist alone one of the two strains produced in firing, namely : the steel tube, wrapped with steel wire, which sustains the effect of the expansion of the gas in the direction of the radius only ; the nut for the breech-screw, connected by bolts to the trunnion-band, the bolts resisting the effort to blow out the breech.

2d. The employment of a steel-wire wrapping, put on under a determinate tension, for the hooping of the gun. By this process not only can the tension of the wire, rolled successively around the gun, be rigorously determined by means of a weight, a fact that cannot be definitely ascertained with the ordinary

* Gun Foundry Board Report.

hooping where the shrinkage always remains more or less uncertain, but, furthermore, the good quality of the steel wire is insured, for the very operation of wire-drawing constitutes a test that eliminates all defects. The wire employed possesses a resistance of 284,000 pounds per square inch, while for the ordinary steel hoops the resistance is scarcely 92,000 pounds, and even then there is no guarantee against defects.

The plans have been drawn up by Captain Schultz in accordance with an understanding had with the Inspector-General of Artillery. Following are some of the principal data relative to the two guns, viz.:

		10 cm.	34 cm.
Total length	feet,	9.68	30.41
Length of bore	do.	8.86	28.99
Length of bore	caliber,	27.3	26
Weight of gun	pounds,	2,704	108,379
Weight of projectile	do.	26.4	924

The diameter of the powder chamber is slightly greater than that of the bore, and its capacity is sufficient to admit of the employment of a weight of charge equal to one-half the weight of the projectile, with the realization of more than 1968 feet velocity.

The "Memorial de Artilleria" of October, 1881, gave the following description of the Schultz 34-cm. steel-wire gun:

The piece is composed of an inner steel tube of 5.5 inches maximum and 3.94 inches minimum thickness, and having a total length of 31.06 feet. From the breech as far as the middle of the chase it is wrapped with steel wire of 0.118 inch diameter, by which the thickness of the wall is increased 4.53 inches from the breech to the axis of trunnions and 2.26 inches for the remainder of the wire-wrapped portion.

A cast-iron casing 0.98 inch thick covers the entire wrapped portion, the object of which is not to support pressures, but simply to inclose and protect the wires.

The interior diameter of the chamber is 14.57 inches; that of the bore proper, 13.39 inches. The length of the chamber is 53.15 inches; the total length of bore is 28.9 feet.

A steel disk 59 inches in diameter and 3.94 inches thick is attached to the piece in rear of the chamber and concentric with it. Twelve cylindrical steel tie-rods, 3.74 inches in diameter, connect this disk with a similar one situated in the axis of the trunnions, the object of which disposition is, to all appearances, to sustain the pressures on the bottom of the bore.

In order to wrap on the wire, the tube of the cannon is placed in a simple, but strong machine that admits of being turned about its axis. At 13 feet to one side is a spindle of timber and iron, similar in form to the cannon, and mounted on a similar apparatus. Between the two is a trench 6½ feet deep by 4.9 feet wide, on the borders of which work pulleys 29.5 inches in diameter. The wire is wound upon the spindle, whence it passes to the pulley fixed

on the edge of the trench, thence to a movable pulley suspended near the trench, carrying a 2200-pound weight, and finally to the steel tube.

This apparatus being slowly turned, the wire is wrapped upon the tube under a tension of 1100 pounds, and after divers trips with the weighted pulley, running over the trench throughout the entire length of the cannon, the operation is terminated.

The steel wire used for the 34-cm. gun has a diameter of 0.118 inch, and its resistance is 284,000 pounds per square inch; the total resistance will be 2,007,880 pounds. Thus the mass of enveloping wire offers four times the resistance of cast-steel.

The pressure extended by the wire upon the steel tube is sufficient to contract its diameter .079 inch.

The weight of the gun amounts to 50 tons, and although the cost cannot be fixed until the current fabrication is known, it would appear as if it has cost less than 28,000 francs.

Of the methods of fastening the wires, Captain Schultz, in his specifications of patents, has given the following:

The method of fastening must meet several requirements; it should be sufficiently simple to occupy but little space; it must be absolutely secure; finally, the fastening must take place while the wire is supporting the coiling weight, and without any variation of its tension. A means of attaining this object consists in squeezing several wires between two pieces with corrugated surfaces, figure 3 (Plate LXI.), intended to produce gentle curves in the wires. The squeezing of these pieces is obtained by screws or by wedges, figure 1, but the means to which I give preference, and which I claim as my invention, consists in inserting the wire into a slit, figure 2, of rectangular section, made in a piece of tempered steel, figures 4, 5. The width of this slit is slightly less than the diameter of the wire. The result is that the wire, being sunk into this slot, is cut against the sharp edges of the steel, two small segments are removed, and the wire forms a real riveting, figure 6. The pieces of steel forming fastenings are set transversely to a channel, figure 2 (Plate LXI.), and figure 3 (Plate LX.), where meet the ends of the wires of all the rows. The wire which it is desired to fix comes on to the edges of the slit, and while still remaining under the tension of the weight which it supports, a blow from a hammer is sufficient to drive it into the slit, and the fastening is thus completed without any variation of the tension.

"For future construction, however, the system of taking up the longitudinal effort with bars is abandoned, and the 34-centimetre gun now at Gâvre is to be returned to Fives-Lille for reconstruction. This will consist in replacing the bars with a jacket shrunk on over the wire wrappings, and which, at its forward end, will hook over the band already shrunk on the gun, and at its rear end be notched into the band containing the breech-mechanism.

Fig. 1.

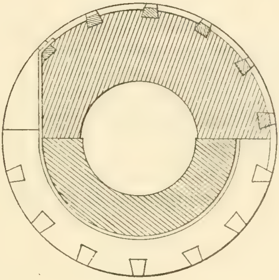


Fig. 2.

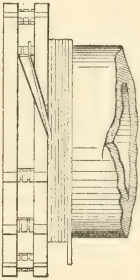


Fig. 3.

Fig. 4. *Fig. 6.*

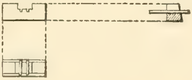
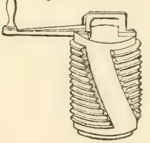


Fig. 5.

Fig. 7.



SCHULTZ WIRE GUN.

> A gun of 10-centimetres built upon this system is now being experimented with at Gâvre, and the results have been sufficiently satisfactory to justify enlarging the chamber for the purpose of testing the gun with increased charges.
>
> The above exhibits the present condition of this problem in France."*

It is rather a subject for rejoicing than of regret that, during the early trials of the Schultz gun, the steel rods gave way and so clearly demonstrated the weakness of a method of obtaining longitudinal strength, that seemed so mechanically impossible even with the skill of the French machinist and the accuracy and precision of his tests. The result has undoubtedly saved the large expenditure for wire guns, manufactured on this principle, which would have been made in France and other countries, the United States not excluded ; and the system has been abandoned, in France at least, for one presenting greater promise of success, and in which the *long jacket* will meet the longitudinal strain.

* Gun Foundry Board Report.

IV.

GERMANY.

SOURCES OF SUPPLY AND CONDITION OF ARTILLERY.

> "Among the places that the Board desired to visit in Europe was included the famous establishment of Mr. Fried. Krupp, at Essen, in Westphalia; and, as in all cases where it was proposed to visit private works, a letter was addressed to Mr. Krupp, through his agent in London, requesting the necessary permission.
>
> The permission was refused."*

The following correspondence relating to this subject will be interesting, not only because it contains Mr. Krupp's reasons for denying the request of the Board, but because it points out the constant and natural desire to lose no opportunity of glorifying the power of his guns, and to conceal, if possible, the processes of manufacture and the systems of fabrication.

BROWN'S HOTEL, DOVER STREET,
London, England, July 30, 1883.

ALFRED LONGSDON, ESQ.,

SIR:—I am requested by the Board appointed by the President, under a late act of the United States Congress, to examine and to report on matters relating to the manufacture of cannon, to address you on the subject of a visit which we desire to make to the works of Mr. Fried. Krupp, at Essen.

From our preliminary conversation of this morning I understand your position to be at the outset as follows: That if the examination of the Board be confined to a study of the works for the purpose of gaining information for our Government, without holding out any prospect of ultimate advantage to the factory through purchase of material, the request for admission will not be granted.

In reply to this I desire to state that though this Board is not authorized in any way to commit the United States Government to any course of action, yet the recommendations that it may make are entirely at its own discretion.

The members of the Board are well aware of the great expense necessary before a gun-foundry establishment can be brought to a state of practical usefulness; they are also aware of the length of time that must elapse before a

* Gun Foundry Board Report.

plant can be established or satisfactory work produced; and, if it should be concluded by the United States Congress to supplement the present inquiry by directing that armaments shall be provided at once, it is very probable that the recommendations of this Board would be to purchase abroad.

In such a case, the information that we might gain by a close examination of the manufacture of steel and the fabrication of guns and ammunition at the works of Mr. Krupp might greatly influence the direction of our recommendations.

If this view of the case will satisfy the implied condition of ultimate profit to the establishment, I will be glad to hear from you to that effect, and I request that this communication may be received as an official application for permission to visit the works.

Very respectfully,

E. SIMPSON,

Commodore, United States Navy, President of the Board.

(Care of B. F. Stevens, United States Dispatch Agent,

4 Trafalgar Square, Charing Cross, London.)

[Fried. Krupp's Cast-Steel Works, Essen, Rhenish Prussia.]

9 NEW BROAD STREET,

London, July 31, 1883.

COMMODORE E. SIMPSON, U. S. N.,

President of the Gun Foundry Board,

Brown's Hotel, Dover Street, W.

SIR:—I am duly in receipt of your esteemed favor of the 30th instant, which accurately recapitulates the substance of our conversation yesterday. I have now fully laid the matter before my Essen firm, and trust in a few days to write you fully thereon, and trust that a satisfactory solution of the question may be found; and in meantime, believe me, Sir,

Yours faithfully,

Pr. Pro. FRIED. KRUPP,

ALFRED LONGSDON.

[Fried. Krupp's Cast-Steel Works, Essen, Rhenish Prussia.]

9 NEW BROAD STREET,

London, August 13, 1883.

COMMODORE EDWARD SIMPSON,

President of the American Artillery Commission.

SIR:— I am now enabled to reply to your valued favor of 30th of July, which has had the consideration of my Essen firm, and I beg to submit to you the following:

As it is presumed that your Commission has for its chief purpose the examination of the ordnance question in its characteristic of artillery efficiency, more than as a system of manufacture, which must be secondary, there does not appear to be so much necessity to see the works at Essen, where no data could be taken as to the value of the Krupp system as pieces of artillery. It would be of much higher consequence to you to examine the question of efficiency by

a course of practice at the artillery practice-ground at Meppen, where guns of different calibers could be fired for all the essential ballistic properties attaching to them.

It is therefore proposed to place at your disposal the practice-ground at Meppen, and to fire there the different guns on the ground for range, accuracy, and general efficiency, and I shall be very glad if this meets with your acceptance. It is, however, of consequence that this should be decided without loss of time, because we are not allowed to fire after *September* 1 *till October* 15, on account of the harvest in the neighborhood. It will, therefore, be essential that the trials take place *this month*, and if you will kindly give me your decision, a programme shall be drawn up for, say, the last days of this month. You may be sure that everything shall be done at Meppen to give you every information upon the superiority of our system of artillery. I shall be glad to have a telegram from you as early as possible, stating your decision, as I am leaving for Essen on Thursday morning.

The works at Essen cannot be seen, as these are closed to all but those who have special business of inspection of war material on order.

I am, Sir, yours obediently,

Pr. Pro. FRIED. KRUPP,
ALFRED LONGSDON.

[Telegram.]

NEWCASTLE-ON-TYNE, ENGLAND,
August 14, 1883.

ALFRED LONGSDON,
9 *New Broad Street, London, E. C.:*

The Board regrets that it will be unable to accept the offer contained in yours of the 13th instant. Letter by mail.

COMMODORE E. SIMPSON,
County Hotel, Newcastle-on-Tyne.

THE COUNTY HOTEL,
Newcastle-on-Tyne, England, August 15, 1883.

FRIED. KRUPP'S CAST-STEEL WORKS, ESSEN, RHENISH PRUSSIA,
9 *New Broad Street, London, E. C.*

SIR:—On the part of the United States Gun Foundry Board, I have the honor to acknowledge the receipt of your favor of the 13th instant, in which I am informed that "the works at Essen cannot be seen, as these are closed to all but those who have special business of inspection of war material on order."

As the application of the Board was for permission to visit the works at Essen, your reply is therefore a notification that the request is refused.

The members of the Board appreciate your courtesy in placing at their disposal the practice-ground at Meppen, and your offer to exhibit the firing of guns for range, accuracy, and general efficiency; but notwithstanding the great

interest that would be taken in such experiments by the members of the Board, it is considered that the object of their mission would not be furthered thereby. With many thanks, therefore, for your considerate offer to view the efficiency of the Krupp manufacture by means of a course of practice, we regret our inability to accept it.

You will allow me to demur to your conclusion that "your Commission has for its chief purpose the examination of the ordnance question in its characteristics of artillery efficiency." On the contrary, it has for its object more the "system of manufacture," and I refer you to my letter of July 30, in which this view is presented.

Very respectfully,

E. SIMPSON,

Commodore, United States Navy, President of the Board.

[Fried. Krupp's Cast-Steel Works, Essen, Rhenish Prussia.]

9 NEW BROAD STREET,
London, August 16, 1883.

COMMODORE E. SIMPSON, U. S. N.,
President of the Gun Foundry Board,
The County Hotel, Newcastle-on-Tyne.

SIR:—I beg to acknowledge your esteemed favor of yesterday, which has been forwarded to Mr. Longsdon, who has gone to Essen.

I have the honor to be, Sir, your obedient servant,

For FRIED. KRUPP,
WALTER COWAN.

ESSEN, RHENISH PRUSSIA,
September 1, 1883.

COMMODORE EDWARD SIMPSON, U. S. N.,
President of the Gun Foundry Board, London.

SIR:—Your favor of 15th ultimo has been forwarded to me here, and I very much regret that you have not accepted my desire to be of such service to you as I could, if not in all the objects of your mission to Europe, still to make yourself acquainted by personal observation of the efficiency and general characteristics of my artillery, for I had conceived that at least this would have formed the first necessity, and that the process of the manufacture of a gun would have been second to the conviction as to which is really the most efficient system of artillery.

If you recollect during our conversation in London I endeavored to clearly point out to you that it was hardly to be expected that the process of manufacturing artillery upon my system could be shown to you, a process only arrived at by an immense expenditure of time and money, while on your side no compensation would be guaranteed, and that we should thus be upon unequal terms; and from your favor of 15th ultimo I can now gather that a simple walk through the Essen shops would even not be all that you would require, but that the system of construction should be made clear to you—an amount of information scarcely to be expected.

I was sincerely desirous of giving you every means of examining my gun as a piece of effective ordnance, and I inclose you a programme I had proposed to myself should be followed, and I think you will be assured that I had every desire of being thus far of service to you. The outlay for such a programme would be £500 at least, so that I was fully prepared to sacrifice this in your interest, and if you can visit the practice-ground at Meppen after 15th October, I will do my utmost still to show you all the courtesy and attention I can in this direction.

Draft of Programme for United States Commission.

Caliber.	Numbers and kind of projectiles.	Pauses for—	Space of time.
			Minutes.
40-centimetre gun	2 common shells		20
		Change of position of frames	15
28-centimetre gun	5 armor-piercing shells		50
	5 common shells		25
		Change of position of frames	15
15¾-centimetre gun	5 common shells		30
		Advance	15
15-centimetre mortar	5 common shells		15
	5 shrapnels		25
		Rest, including advance	120
8.7-centimetre gun	5 shells, 5 shrapnels		40
Light 7.5-centimetre gun	5 shells, 5 shrapnels		30
7.5-centimetre mountain gun	5 shells, 5 shrapnels		30
15.5-centimetre shield gun	10 shells		20
15-centimetre pivot gun	5 shells		20
			470

470 minutes = 7 hours 50 minutes.

Should you desire to have a series of reports of trials with my guns of various calibers, showing their capabilities, I shall be happy to have a collection of them made for your disposal. I am, Sir, yours, very truly,

Pr. Pro. FRIED. KRUPP,
ALFRED LONGSDON.

PARIS, FRANCE, *September* 17, 1883.

FRIED. KRUPP, ESQ.,
Per Alfred Longsdon, Esq.,
Essen.

SIR:—On my return from an extended tour in France, I find your favor of the 1st instant, which I have laid before the Commission, and to which I hasten to reply.

The "draft of a programme for the United States Commission," inclosed in your letter, is of a most elaborate character, and very strongly confirms the statement therein that you were desirous of giving the Commission "every means of examining my [your] gun as a piece of effective ordnance," and it is hardly necessary for me to repeat that such an exhibition would be of the greatest interest personally to the members of the Commission. The estimated outlay for such a programme (£500) impresses us with the extent of the sacrifice you were prepared to make in this regard in the interest of the Commission.

The question of the effectiveness of the Krupp gun as a piece of ordnance, however, is not one which at this day can be disputed. The battle fought at Meppen in 1879, though bloodless, and without an enemy in the field, settled this question most decidedly, and you cannot suppose that the members of this Commission are ignorant of the results that have ensued. It is to be regretted that no representatives from the United States assisted at those experiments; but the results are known throughout the world. To witness a partial repetition of them would be excessively interesting, but it would impart no new information.

You will thus see that a "personal observation of the efficiency and general characteristics of my [your] artillery" was not necessary in order to satisfy us of its power; and as the time at our disposal was limited and our course of investigation indicated, we were forced to suppress personal inclination, and to conclude that time spent as you proposed would not be justified by the especial object of our mission. The courtesy of your proposition was thoroughly recognized, and I trust that our reasons for declining your modification of our request are accepted as a necessity arising out of the circumstances in which we are placed.

After being notified by you that the "works at Essen cannot be seen, as these are closed to all but those who have special business of inspection of war material on order," the Commission established for itself a programme, including a visit to the Aboukhoff Works at Alexandrovsky, which will prevent it from entertaining the idea of visiting the practice-ground at Meppen after the 15th of October, as suggested in your favor of the 1st instant, to which this note is a reply.

In conclusion, I desire to say that this Commission, though organized by act of Congress, and with its members appointed by the President of the United States himself, does not presume to question the perfect right of the authorities of any establishment to exclude it from its premises. Such rights are exercised by Governments, and such action is within the rights of any private corporation, and I deprecate the impression that may be conveyed that the non-attendance of the Commission at Meppen is the result of its exclusion from Essen.

The Commission is organized as a Gun Foundry Board; its essential work concerns itself with the arrangement of shops, the selection and position of tools, machines, &c.—in a word, with "installation." Matters of manufacture of metal, construction of guns, &c., come in as incidental, and bear much on the special object of its mission; but *gun-practice* is a luxury which can only be

indulged in when the more essential features of its work do not engage the attention of the Commission. Very respectfully,

E. SIMPSON,

Commodore, United States Navy, President of the Board.

> " From the above statement it will be seen that the Board is unable to submit any information founded upon personal observation. For the general purposes, however, of this report the following statements will be appropriate :
>
> With the exception of the small gun-factory at Spandau, near Berlin, where a limited number of cannon up to 15 centimetres and some rifled mortars are fabricated, the source from which the armaments of Germany are supplied is the establishment of Mr. Fried. Krupp. The Government has no control over the works ; consequently the principal dependence is on this private company. Owing to the great enterprise exhibited in the management, and to the support of the Government, the establishment has, for many years, enjoyed a monopoly of the manufacture of cannon for Germany, and it has been enabled to furnish guns to many other powers, notably to Russia." *

It is to be regretted that the Board was refused permission to visit the works at Essen, when every other establishment in Europe, producing gun material, so generously and courteously opened its doors. The Board was undoubtedly denied the privilege of obtaining much valuable information from their recent development and present condition.

Many descriptions of Mr. Krupp's steel works have been published, but nearly all have emanated from him or from his assistants, and simply praise the methods and productions without giving any reliable facts in regard to the manufacture or fabrication. Two members of the Commission, however, had previously visited Essen, and there exists information obtained from other visitors.

The situation of Essen has greatly aided Mr. Krupp in his success. Surrounded by railroads, near the Rhine, and in the midst of excellent coal-mines, producing the most suitable material to be found in Germany for metallurgic purposes, it can be speedily and cheaply supplied.

* Gun Foundry Board Report.

In the last century it belonged to a lady abbess, but after 1815 it came under Prussian rule, and more than fifty years ago discovered a workman, Mr. Fried. Krupp's father, who established a small factory.

Like Creusot, the little village did not at first contribute much to the growth of the establishment, for the workmen had to be sought in all parts of Germany; but Essen and the surrounding towns have grown rapidly, until to-day the country resembles the St. Étienne-St. Chamond section of France, in chimneys, smoke, and industrial activity.

The following extract from the report of Consul J. F. Potter, of Crefeld, December 18, 1883, will give some information that was communicated by Mr. Krupp, his assistants and engineers:

Mr. Krupp's unceasing efforts to produce a quality of cast-steel perfectly adapted to the manufacture of fire-arms dates from the year 1840. In 1847 he constructed a three-pounder steel gun, which was sent to Berlin. In the year 1849 this gun was there tested in the presence of a committee on ordnance composed of Prussian artillery officers, and the results were satisfactory beyond expectation.

This gun, as well as others made soon after, was a smooth-bore muzzle-loader. The bronze and cast-iron guns of that date served as models.

The first steel rifled cannon were manufactured for the Berlin Government in 1855. These guns were at the beginning constructed with double wedge and piston fermeture, after models approved by Prussian artillery officers.

In 1851, Krupp sent to the international exhibition at London a steel casting weighing 42 tons, and a 6-pounder cast-steel cannon, which were regarded at that date as remarkable for solid steel productions.

In 1855, he exhibited in Paris a 12-pounder steel shell gun, and in 1862 produced a steel casting weighing 20 tons, and steel cannon weighing from 650 lbs. to 9 tons.

In 1867, Krupp constructed a 14-inch cannon weighing 50 tons, which was tested thoroughly, producing surprising results.

Crucible steel, in Krupp's works, is produced in the following manner:

From the iron-ore mines belonging to the firm, are selected the purest ores, and those which are known by tests and experience to be most suitable for crucible steel. In blast-furnaces especially constructed for the purpose these ores are converted into pig-iron of a peculiar chemical composition. By the puddling process this iron is changed into steel and wrought-iron containing a fixed quantity of carbon. The puddled steel is then rolled into bars of three-fourths of an inch square, and these, after being tempered, are broken into small pieces from 2 to 4 inches in length.

The wrought-iron is rolled into bars one and one-fourth inch broad and one-third of an inch thick, and are then also cut into 2 to 4-inch pieces. By competent men each of these small pieces is carefully examined as to its proportions of carbon, and when the examination and the selection of the proper pieces are completed, this constitutes the material destined for the crucible.

In order to obtain from it a product containing a fixed percentage of carbon, it must be previously calculated what are the proportions of special qualities of steel and wrought-iron that are to be put into the crucibles. These quantities are carefully weighed, and each crucible receives about 84 pounds of the materials.

The crucibles are made by an improved process from materials particularly adapted to the purpose. They must be strong enough to endure the pressure of the contents in cold, and in heat of about 2000 degrees, and so solid and clean as not to impart any foreign substance to the steel which is melted in them. Upon the proper construction of these crucibles largely depends the success of gun castings. The process of making them is one of the secrets which is most carefully guarded in the Krupp establishment. After being filled and hermetically closed, the crucibles are subjected to a preliminary warming, and are then put into melting furnaces especially constructed to receive them.

The process of casting requires, under the Krupp system, great skill on the part of the workmen, who are carefully trained for the purpose. Sometimes 1200 men are required at the same moment to aid in casting a 60-ton steel casting. They must carry, with great caution, 1500 or more crucibles to the place of casting, and the slightest inattention may cause not only the failure of the casting, but result also in serious accidents to persons and property. Even after the metal is poured into the mould, great care and watchfulness are necessary in order to secure complete success. The castings are cylindrical in form, and the various parts of the gun are formed from them by forging, which has the double purpose of greatly improving the metal, and, of course, giving it shape. Great difficulties are encountered in performing this work. Preparatory to forging the great ingot, it must be subjected very slowly to a certain and precise degree of heat, which shall be exactly equal throughout the entire mass.

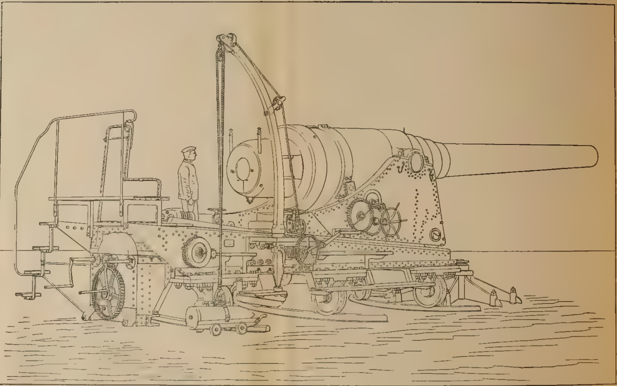
The forging process requires vast arrangements, on account of the immense weight of the pieces which are to be handled, one of which sometimes weighs more than 60 tons. The steam-hammer now in use for this purpose weighs 50 tons, and has a stroke of 10 feet. Another hammer is now being constructed of much greater efficiency, weighing about 150 tons, which will cost over ten millions of marks, *or two and one-half millions of dollars* ($2,500,000).

Mountain guns are finished in two months after work on them is commenced, while two years are required to manufacture a 16-inch gun of 35 calibers length.

Mr. Krupp is now engaged in constructing upon the same principle as the gun above mentioned, 40-centimetre (16-inch) guns, of 35 calibers length, weight 121 tons, for the Italian Government. Ten guns of this latter description have been ordered, it is said, at a cost of 894,000 francs each, for the purpose of coast defence.

It is also stated that the Chinese Government have ordered guns, for coast defence and naval purposes, of *similar dimensions* and power, which are in process of construction at this time by Mr. Krupp.

The following statistics show the present extent and capacity of Krupp's works, and the rapidity of the increase in their dimensions within the last ten and twenty years:



KRUPP 30.5 Cm. NAVY AND COAST B. L. R. ON COAST CARRIAGE.

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In 1860, the number of workmen employed at Essen was 1764; in 1870 the number had increased to 7084.

The total number of persons employed at this time is about 20,000.

The number comprising the families of those employed in the establishment, including 13,000 school children, is 45,776, making a total of 65,381 persons dependent upon the works for support. Of this number 19,000 live in dwellings belonging to the firm of Krupp.

At present Krupp's works comprise the following departments:

1. The great establishment at Essen.
2. Three coal mines near Essen and Bochum.
3. Five hundred and forty-seven iron-ore mines in Germany.
4. Various iron-ore mines in North Spain, near Bilbao.
5. Four blast-furnace works near Duisburg, Neuwied, and Sayn in Prussia.
6. Practice grounds for gunnery trials at Meppen, 10½ miles long.
7. Practice grounds for gunnery at Dälmen, 4½ miles long.
8. Four ocean steamships.
9. Various clay and sand-pit quarries.

In the departments numbered 1 to 5 there are in active operation at this date: 11 blast furnaces; 1542 other furnaces of different kinds; 439 steam boilers; 82 steam-hammers from 1 to 50 tons weight; 21 rolling mills; 450 steam engines, from 2 to 1000 horse-power each, together making 18,500 horse-power.

The total production of the Essen works alone, in 1881, amounted to 260,000 tons of steel and wrought-iron, which was worked up on the premises into war and "peace materials" ready for use.

The consumption of coal amounts to 3100 tons per day.

About 1500 tons of iron ore are daily worked off in the blast furnaces.

To perform the work at the Essen works alone there are required 36½ miles of railway track; 28 locomotives; 883 cars; 69 horses and 191 carts; 40 miles of telegraph lines, 35 stations, and 55 Morse machines; 1 chemical and one physical laboratory; 1 photographic establishment; 1 lithographic establishment; 1 printing office, with 3 steam and 6 hand presses; 1 book-bindery; and a standing fire brigade of 63 men who do no other work.

To the supply establishments belonging to the works, which are maintained for the benefit of employees, in 1882 goods to the value of nearly 4,000,000 of marks were delivered.

These establishments comprise 1 hotel (an excellent one); 8 beer saloons; 1 seltzer-water saloon; 1 steam flour-mill; 1 large bakery; 1 slaughter house and butcher shop; 1 tailor shop; 2 shoemaker shops, and 46 retail stores, where employees can purchase at cost prices, 5 per cent added.

More than 3000 well-built dwellings have been erected for the workmen and their families. Robert P. Porter, in his notes on "Industrial Germany," has described the dwellings and surroundings in the following extract:

The buildings have two or three floors, are constructed partly of stone and partly of frame-work, and are surrounded as much as possible with gardens. The single dwellings, which, besides cellarage and garret, have from two to

four rooms, are self-contained and separated from the other dwellings. The letting to lodgers is permitted only in dwellings of three to four rooms, and must receive the special permission of the central committee appointed for maintaining cleanliness and order. Even in a place like Essen, which is above the average, there is a marked difference between the Continental and American workingman, and the condition of workers here will not compare with the advanced condition of the artisan in such places as Johnstown and Pullman in our own country (United States). The single men at Krupp's works are provided for in a large boarding-house, capable of keeping 1800 boarders. There are sick and pension institutions, out of the funds of which, temporary support and pensions are paid to members who have been disabled in the service of the firm, or to their widows; also to those who have worked for many years and are too old for further service. There are also a hospital, bathing establishment, life insurance union, and primary and industrial schools, all connected with the firm.

In 1859, Mr. Krupp planned his 50-ton hammer, foreseeing that such an instrument for forging would give him a great advantage over other steel workers. An excavation was made to solid rock, and upon a foundation of masonry, heavy oak beams were placed to receive layers of cast-iron, made in cylinders cast in segments, and firmly joined together. Upon this substructure the anvil-bed was secured, the whole forming a platform upon which rested the movable anvil-blocks of the various forms required.

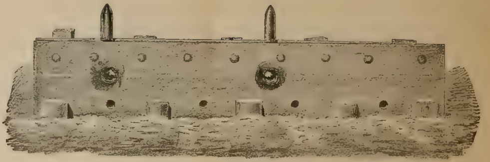
The hollow cast-iron supports of the hammer are secured to the anvil-foundation. They are curved, are 9.8 inches thick, and have a maximum circumference of 19 feet 6 inches, widening and flattening as they meet over the anvil. The legs are 23 feet apart, and 16 feet 5 inches high, measured from the under side.

A series of separate vertical foundations have been constructed around the bed to isolate it from that portion of the ground that bears the supports of the steam-cylinder. Mr. Krupp considers that this arrangement has added a great deal to the successful working of the hammer, but the vibrations are very severe, and are felt at a great distance from the works.

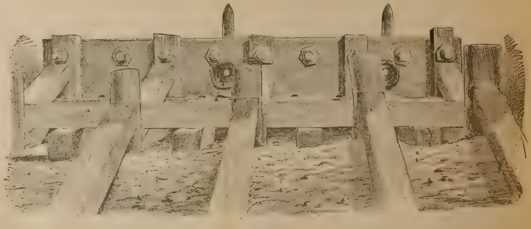
The cylinder has an interior diameter of 5 feet 11 inches, and the stroke of the piston is 9 feet 10 inches. To prevent accident, all of the parts were constructed of very large dimensions. The face of the tup is steel. All of the parts of the hammer and its accessories were manufactured at Essen.

Four 50-ton cranes serve the hammer. The heating-furnaces are fitted with movable soles, are 9 feet 11 inches high and 8 feet 2 inches wide.

The cost of this hammer is said to have been 2,800,000 francs.



FRONT VIEW



REAR VIEW

EXPERIMENTS ON ENGLISH ARMOR WITH KRUPP'S 15 Cm. B. L. R.

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> "As to the condition of the steel manufacture as relates to cannon, it is known that it was the practice to cast gun ingots exclusively of steel prepared in crucibles; ingots of the weight of 80 tons have been cast from crucibles more than 12 years ago. The Board is not able to state whether gun ingots are now cast exclusively from crucibles or whether they are now made from open-hearth furnaces." *

It has been recently stated, however, by visitors that Mr. Krupp continues to use crucible steel alone for ordnance purposes because he considers it the best. But as this information was given by Mr. Krupp's representatives, at the same time that he stated "it was hardly to be expected that the process of manufacturing artillery upon my system could be shown to you," it cannot be accepted as indicating in any way the kind of steel he does use.

When we consider the advances made in the manufacture of German ordnance, it is improbable that Mr. Krupp still adheres to the use of crucible steel only when he has a dozen open-hearth furnaces, some fitted with rotary hearths; and, too, after it has been shown that all the skill and caution, in the individual handling of pots containing less than a hundred pounds of metal, cannot compare with the mechanical improvements of the open-hearth process, which produces such uniform results. The existence of a plant of 1500 crucibles undoubtedly has more bearing upon the question of its use by Mr. Krupp than the fact of a superiority of material.

Mr. Krupp's success in ordnance is largely due to his early acceptance of steel for all the parts of a gun, and to his careful inspection and acquisition of the improvements and inventions of manufacture and fabrication, which the liberality of the German laws permitted him to use, in some cases without remunerating the patentees.

Of his steel plant, Holley, in 1881, gave the following:

> There are 12 open-hearth furnaces, of which from 4 to 9 are running, according to the state of orders. During three years, nearly all the open-hearth steel produced in these works was made from about 5 tons of washed pig and 2 tons of scrap per open-hearth furnace heat. The open-hearth charge usually consists of 5 to 5½ tons of washed pig and 2 to 2½ tons of scrap, not pre-heated. With this charge, a half-ton of ore is used in the furnace; but with a 7 to 8-ton charge of washed pig, without scrap, one ton of ore would be used. Some 8-ton heats, with 3 tons of scrap, were observed. The time of making a 7-ton open-hearth heat averaged 7 hours, and the time of repairing the furnace be-

* Gun Foundry Board Report.

tween heats was about one hour. The increased output, by using washed pig in the proportion mentioned, as compared with the old pig and scrap process, is about one ton per furnace per shift. The waste of iron is also considerably decreased by reason of the low silicon. The principal products are tires, axles, plates, and forgings. I saw, nearly completed, a new ram or stem-post for the ironclad Koenig Wilhelm ; it was a complex forging from open-hearth *fluss-eisen* containing 0.08 carbon, and made from washed metal.

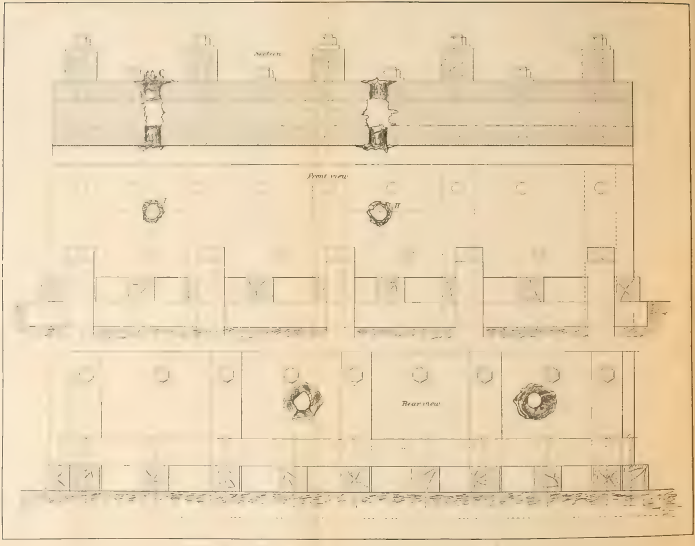
The Krupp washing furnace is a regenerative gas-furnace. It has a Pernot revolving hearth, of 12 feet external diameter and 3 feet depth. The four regenerator chambers have 780 cubic feet capacity, which is about the same as the average regenerator capacity of open-hearth steel furnaces of equal tonnage. The lining is 13 inches thick on the sides, and 9 inches on the bottom, thus giving a hearth 9 feet 10 inches by 2 feet 3 inches deep. The lining is composed of lumps of highly refractory ores roughly fitted together, the interstices being filled with fine ore, and the whole being glazed at a melting temperature. Large lumps are placed on the sides and smaller lumps on the bottom. When the fine ore has melted and run between the lumps, more fine ore is put on and melted, until the lining becomes monolithic. The hearth is then fettled.

The fettling averages 20 per cent on the pig-iron charge, but more is used with irons very high in phosphorus. The charges run out very clean and hot. After each heat, the gas is turned off for five minutes while the tap-hole is turned on the high side and redressed. The bottom sides, or lower part of the slopes of the hearth, which have been most eaten out during the process, are then filled with fettling ore wet up with just enough water to make it stick together, so that it can be readily handled, and so that it will not blow over the regenerators. A long-handled, large, shallow spoon is placed across a bar in the charging-door. One workman shovels the fettling into the spoon ; another throws it out of the spoon against the slope. After each two or three spoonfuls, the hearth is revolved a little, so that the fettling is always conveniently dropped in the same place relatively to the door. This operation occupies 16 to 20 minutes. The fettling first put in is red by the time the last is in place.

The fettling should contain a minimum of silica, 6 per cent, and a maximum, 15 per cent. If the silica exceeds 15 per cent, or if the silicon in the pig exceeds 1 per cent, it is best to add as much lime as there is silica in the ore (a little lime is always useful) ; if the silica is less than 6 per cent the fettling will not adhere.

The maximum temperature, which is above high puddling heat, but considerably lower than open-hearth steel heat, is kept up between, as well as during the operations ; this temperature slightly melts the surface of the fettling, and sometimes melts furrows 2 or 3 inches deep in the less refractory parts. During this time, the hearth is revolved 3 or 4 turns per minute.

The charge is from 5 to 7 tons—usually 5 tons. Messrs. Bender and Narjes, who have developed the process, insist that at least 0.30 per cent of manganese is essential to the most economical result, even if it has to be added in the shape of spiegeleisen. They prefer 1 per cent manganese. It seems quite certain from analysis, that manganese protects carbon from oxidation, and so keeps the bath very hot and fluid until the phosphorus is removed. Carbon should



EXPERIMENTS ON ENGLISH ARMOR WITH KRUPP'S 15 Cm B L R

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also be as high as possible ; at least 2.7 per cent. Silicon should be as low as possible. If it is higher than 1 per cent, lime must be added ; there is a greater waste of fettling, and the operation is prolonged. The silica in the slag must be less than 20 per cent ; if it runs from 20 to 30 per cent, it so impairs the basicity of the slag that only 20 to 30 per cent of phosphorus can be got out of the iron.

For steel, the pig-iron used averages 0.70 to 0.80 in phosphorus ; this element, after washing, is reduced to 0.10 to 0.15, and may be still further diluted by pure scrap. Silicon and manganese are reduced to traces. A large amount of *fluss-eisen* is made containing phosphorus, 0.15 to 0.20 ; but the carbon is about 0.08 and the silicon very low. This metal has an elastic limit of 15 to 18 tons, an ultimate tenacity of 26 to 30 tons, and an elongation of 23 to 29 per cent.

In the washing process, the charge begins at once to bubble in the Pernot hearth, from the mechanical action of the pouring. As soon as it is all in, the revolutions of the hearth are increased to 11 per minute. Large blotches of slag soon appear, with iron spouting through ; but this is no criterion of the state of the bath. Usually in 2½ or 3 minutes from the time the iron begins to run into the furnace the bath rises and the slag flows more or less out of the joint between the revolving-hearth and the roof. If the slag rises earlier than 2 minutes, the speed of the rotation is decreased. The rising of the bath somewhat represses the bubbling. The rising lasts about 2 minutes ; and after it has fallen a little, the carbonic oxide, with its characteristic flame, begins to blow out ; the bubbles on the surface of the bath increase largely in diameter, up to 6 or 8 inches, and are broken here and there by iron breaking through ; the ebullition seems a little more sluggish than that at the first stage of the operation, but the bubbles are much larger, and increase more and more in size and number as the operation advances. The spouting iron, towards the last, rises from 6 to 10 inches above the bath, and presents the appearance of a miniature forest of trees. The bubbling is not, however, as lively as that of the pig-and-ore bath, because the temperature is lower. The close of the operation is indicated by a rather sudden and voluminous generation of carbonic oxide, and of spouting due to its release. The tap-hole is then brought around to the spout, and the furnace is tapped as soon as possible. Flame constantly blows out of the openings in the furnace, from three causes—the slight gas plenum, the rapid revolution of the hearth, and the generation of carbonic oxide.

The time of the washing operations witnessed averaged between five and eight minutes. Rich fettling of course shortens the time. The tapping, from stopping the rotation of the hearth to opening the tap, averaged two minutes, and the time from stopping the hearth to filling the ladle for the open-hearth, or the pig-bed for puddling, averaged five minutes.

The washed iron invariably runs out much hotter than when it went in ; no iron nor slag remains in the furnace. The ladle for one line of open-hearth furnaces stands in a pit about 20 feet from the tap-hole ; the other ladle is about 50 feet away. Some slag runs out with the last of the metal ; this runs over the ladle into a spout which conducts it to a slag-pit in the floor. When

the metal is all out, a section of the furnace spout is moved laterally, to run the bulk of the slag into a pit. One ladle sits in a car which is raised to the general level by a hydraulic lift and is then drawn to the front of the furnace; the ladle is tapped into a spout 12 feet long, leading into the furnace-door. The other ladle is raised out of its pit by a locomotive crane, which also transports it to the furnace. The metal may be held in the ladle twenty minutes without perceptible chilling. The pig-bed for receiving washed iron for puddling begins about 20 feet from the furnace tap-hole. The slag that runs out with the metal is partly stopped by a skimmer and partly run off the end of the sow. When the metal is all out, a section of the spout is moved laterally to run the slag into a pit, or the furnace tap-hole may be moved laterally, to run it on the floor. These arrangements are obviously not so convenient as could be made in a new plant. The heat radiated from the stream of very hot washed metal, and more particularly from the voluminous slag, if it spreads on the floor, is very great. It is important, therefore, to provide pits in which the slag may be concentrated; from such pits it may also be removed with the minimum of labor. The space on the tapping side should be large and well ventilated.

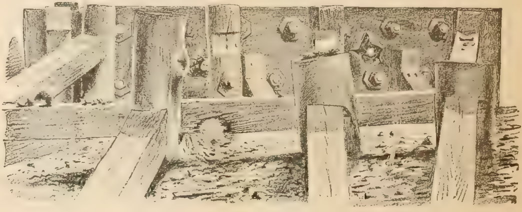
The proportion of phosphorus eliminated by this process is not so great as by the Thomas & Gilchrist (Basic) process; the efficiency, however, of lime linings and additions in the open hearth is yet to be tested. The Krupp washing has little or no value in connection with the Bessemer process. The Siemens direct process also yields a material adapted to the open-hearth, more free, not only from phosphorus, but from carbon, than the Krupp washed metal, and in better condition to be converted rapidly into steel, but it must be admitted that this process is cheap, uniform, and convenient, and it is no longer in any sense experimental.

The old Bessemer plant of 5 vessels is naturally of the worst English type, as it was one of the first in Europe. The new plant has 4 vessels in one row, and four in an opposite row, with one at the end, and a common low pit or series of pits between. This is bad enough, but the rows of cupolas on both sides make the temperature and the inconvenience almost intolerable. As no blast-furnaces are near, no direct metal is used. There are 8 cupolas with fore-hearths, each having 6 feet internal diameter, and two 16 by 18 inch tuyeres—a very wide and apparently successful departure from general practice, as the furnaces melt 12½ pounds of pig per pound of coke. The vessel bottoms are rammed around rods, from a clay and ganister mixture, which has been got at by long experimenting. The bottoms are dried—not burned—and generally last about 30 heats. The air-holes are inclined, to give a spiral motion to the bath. Ingots are top-cast through ¾-inch nozzles.

Siemens gas-producers are employed with improvements in charging and pre-heating apparatus.

"The following is the present condition of the German artillery, taken from official sources:

FRONT VIEW



REAR VIEW

EXPERIMENTS ON ENGLISH ARMOR WITH KRUPP'S 15 Cm. B. L. R.

the metal is all out, a section of the furnace spout is moved laterally, to run the bulk of the slag into a pit. One ladle sits in a car which is raised to the general level by a hydraulic lift and is then drawn to the front of the furnace; the ladle is tapped into a spout 12 feet long, leading into the furnace-door. The other ladle is raised out of its pit by a locomotive crane, which also transports it to the furnace. The metal may be held in the ladle twenty minutes without perceptible chilling. The pig-bed for receiving washed iron for puddling begins about 20 feet from the furnace tap-hole. The slag that runs out with the metal is partly stopped by a skimmer and partly run off the end of the sow. When the metal is all out, a section of the spout is moved laterally to run the slag into a pit, or the furnace tap-hole may be moved laterally, to run it on the floor. These arrangements are obviously not so convenient as could be made in a new plant. The heat radiated from the stream of very hot washed metal, and more particularly from the voluminous slag, if it spreads on the floor, is very great. It is important, therefore, to provide pits in which the slag may be concentrated; from such pits it may also be removed with the minimum of labor. The space on the tapping side should be large and well ventilated.

The proportion of phosphorus eliminated by this process is not so great as by the Thomas & Gilchrist (Basic) process; the efficiency, however, of lime linings and additions in the open hearth is yet to be tested. The Krupp washing has little or no value in connection with the Bessemer process. The Siemens direct process also yields a material adapted to the open-hearth, more free, not only from phosphorus, but from carbon, than the Krupp washed metal, and in better condition to be converted rapidly into steel, but it must be admitted that this process is cheap, uniform, and convenient, and it is no longer in any sense experimental.

The old Bessemer plant of 5 vessels is naturally of the worst English type, as it was one of the first in Europe. The new plant has 4 vessels in one row, and four in an opposite row, with one at the end, and a common low pit or series of pits between. This is bad enough, but the rows of cupolas on both sides make the temperature and the inconvenience almost intolerable. As no blast-furnaces are near, no direct metal is used. There are 8 cupolas with fore-hearths, each having 6 feet internal diameter, and two 16 by 18 inch tuyeres—a very wide and apparently successful departure from general practice, as the furnaces melt 12½ pounds of pig per pound of coke. The vessel bottoms are rammed around rods, from a clay and ganister mixture, which has been got at by long experimenting. The bottoms are dried—not burned—and generally last about 30 heats. The air-holes are inclined, to give a spiral motion to the bath. Ingots are top-cast through ¾-inch nozzles.

Siemens gas-producers are employed with improvements in charging and pre-heating apparatus.

"The following is the present condition of the German artillery, taken from official sources:

	Calibers.
8-centimetre pivot-cannon	...
8.4-centimetre field-gun	25.6
8.7-centimetre	50
10.5-centimetre	...
10.5-centimetre	35
10.7-centimetre pivot-cannon	...
12-centimetre, navy and coast, light	25
12-centimetre	30
15-centimetre pivot-cannon	...
15-centimetre siege-gun	...
15-centimetre, navy and coast	25
15-centimetre	30
15-centimetre, navy and coast	35
21-centimetre	30
21-centimetre mortar	...
24-centimetre, 19 tons	30
24-centimetre, 21 tons	35
26-centimetre	35
28-centimetre	35
30.5-centimetre, light, 32 tons	25
30.5-centimetre, heavy	25
30.5-centimetre, 43 tons	30
30.5-centimetre, navy and coast, 48 tons	35
35.5-centimetre, 51 tons	25
35.5-centimetre, 68 tons	30
35.5-centimetre, 76 tons	35
40-centimetre, 72 tons	25
40-centimetre, 97 tons	30
40-centimetre, 109 tons	35" *

Plate LXII. represents a 30.5-centimetre Krupp breech-loading rifle mounted on a coast carriage and fitted with all its accessories for manipulation.

> "The power of the Krupp gun is best illustrated by the reports of firings that took place at Meppen in 1879 and subsequently. These reports are available for reference." *

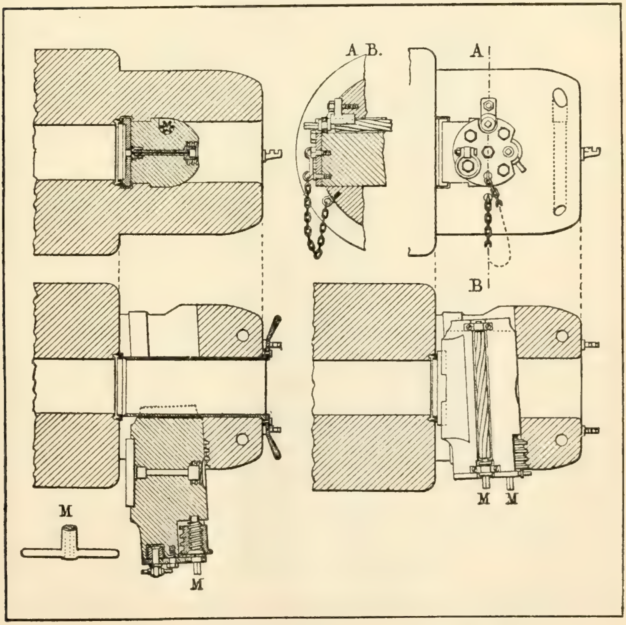
Plates LXIII., LXIV. represent the results of experiments that took place at Meppen on the 28th and 30th of March, 1882, and illustrate the power of the Krupp 15-centimetre B. L. R. The target consisted

* Gun Foundry Board Report.

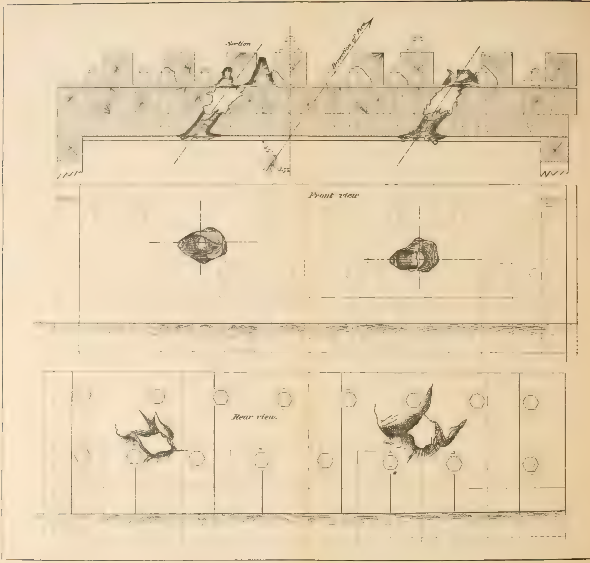
of two 7-inch wrought-iron English armor-plates, with 9.84 inches of oak between. The projectiles were two steel battering shells. The angle of fire was perpendicular to the plates. The range was 164 yards; the charge of powder, 37 pounds; the weight of projectiles, 112 pounds; initial velocity, 1770 feet.

Plates LXV., LXVI. represent the results of experiments with the same gun, under similar conditions, except that the target, in this case, consisted of one 8-inch wrought-iron English armor-plate backed with 9.84 inches of oak and an inner iron skin of 1-inch thickness. The angle of fire was 35° with the perpendicular and 55° with the plane of the plate.

> "The *material* used in the construction of the Krupp guns is steel.
>
> The system of *construction* is that of a built-up gun, with tube and hoops. In the larger guns of latest design the first hoop shrunk on the rear of the tube is lengthened (Plate LXVII.), resembling the jacket of the Vavasseur design.



KRUPP CYLINDRO-PRISMATIC FERMETURE.



EXPERIMENTS ON ENGLISH ARMOR WITH KRUPP'S 15-Cm. B. L. R.

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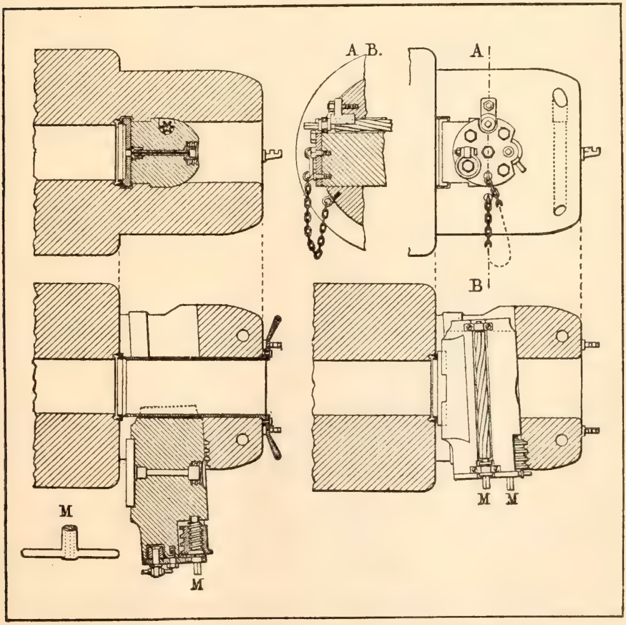
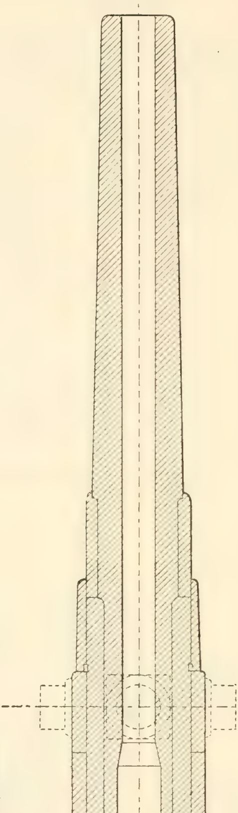


KRUPP CYLINDRO-PRISMATIC FERMETURE.



Scale, ½" = 1 Foot.

15-CENT. 78 CWT. KRUPP B. L. R.

The *fermeture*, page 775, is the cylindro-prismatic wedge, modified from the original invention of Mr. Broadwell, and adopted by Mr. Krupp. The *gas-check* is also the invention of Mr. Broadwell and bears his name." *

Captain Gadaud, in his "Carnet de Notes et Renseignements" for 1881, states the following concerning the German artillery:

The cannon for the German Navy are constructed by Mr. Krupp, at his Essen Works. They consist of a steel tube strengthened by hoops of the same material. There are two systems; in the latter, the hoops are more numerous and smaller than in the former.

The chamber is eccentric; that is, its axis does not coincide with that of the tube; the lower surface of the chamber is on a level with the lower surface of the tube, figure 2. This is done so as not to require the projectile to rise, as in figure 1, in order to enter the tube.

Fig. 1.

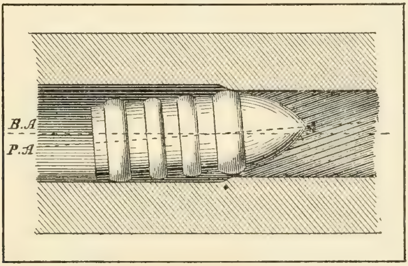
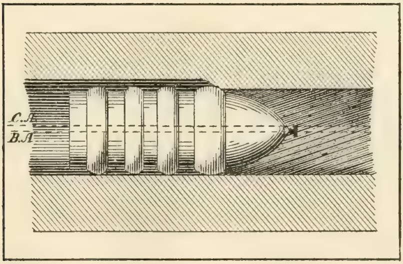


Fig. 2.



B. A. axis of bore. C. A. axis of chamber. P. A. axis of projectile.

* Gun Foundry Board Report.

The Broadwell ring is employed for a gas-check, and the breech is closed by a cylindro-prismatic wedge, page 775, which moves horizontally in an opening in the breech. This lateral movement, by which the breech is opened or closed, is produced in the large calibers by an endless screw. A loading-tube is used for guns of 15 centimetres and above. In the smaller calibers, the extremity of the wedge is pierced for the entrance of the charge. In every case a screw assures perfect fermeture or release of the wedge.

The *vent* is in the wedge and a prolongation of the axis of the piece, when the breech is closed. The friction-primer is a cylinder containing a hammer actuated by a spring and trigger. It screws into the vent and terminates in a case composed of two parts screwed together; one contains the friction material, and the other, the pin that receives the blow from the hammer and transmits it to the detonator.

The grooves are spiral and increasing. The rotating-rings, which were composed originally of lead, are similar to those we (the French) adopted in 1870.

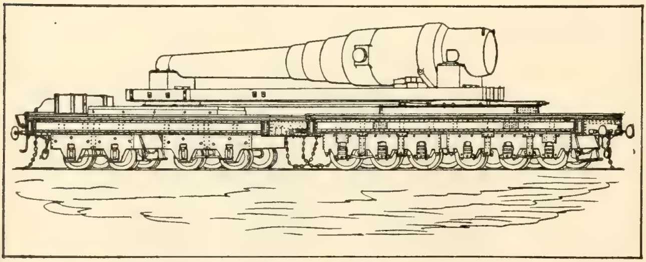
In many of the Krupp guns, the rifling is cuneiform and progressive, the width and depth of the grooves diminishing towards the muzzle. This arrangement compensates for the wear on the rotating-ring.

The projectiles are of steel and chilled cast-iron. They are usually three calibers long, but sometimes attain a length of four calibers.

While the largest gun being fabricated at Essen had a diameter of bore of 40 centimetres, among others it is proposed to manufacture one of 46 centimetres caliber, to weigh 124 tons, and firing a projectile of 2320 pounds. The increased length of bore and longer projectiles are important changes in the Krupp development.

"The Board can give no information upon the subject of wire-construction in Germany."*

Krupp's wagon-truck for the transportation of his 71-ton and heavier guns differs materially from other constructions in that the axis of the gun is carried much higher, and a double truck is em-



KRUPP'S WAGON-TRUCK AND 40-Cm. B. L. R.

* Gun Foundry Board Report.

ployed whereby the platform pivots as the bogies follow the curves of the road.

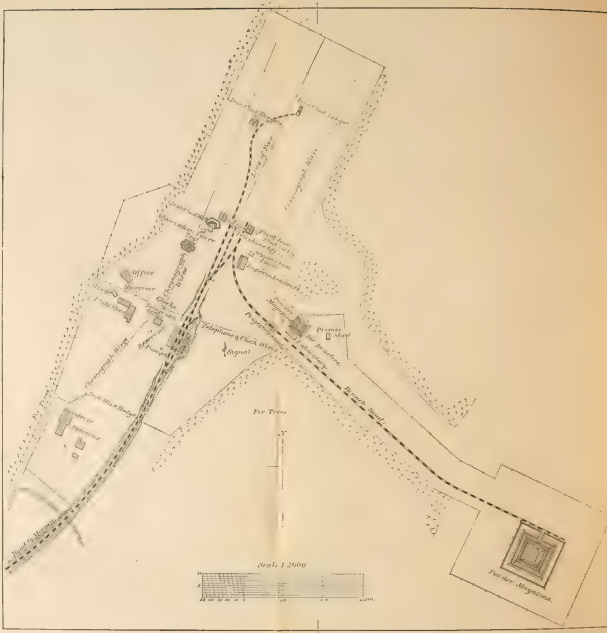
With the range of 8000 yards at Dälmen, Westphalia, and the firing-ground at Meppen, Mr. Krupp has provided ample means for testing and proving his ordnance; and, at the latter place, probably has the largest and best equipped proving-ground in the world.

As will be seen in Plate LXVIII., it is perfectly arranged, and fitted with platforms, targets, sheds, magazines, laboratory, signals, telephones, and chronographs with their connecting wires, repair shops, and observation towers—everything necessary for a perfect service. It is $10\frac{1}{2}$ miles long and $2\frac{1}{4}$ wide.

> "The e[illegible] point to be observed in this notice is that the main su[illegible] of the artillery of Germany is drawn from one private firm. In this respect the method differs from that followed either in England or in France. It goes without saying that the Government pays a high price for the manufactured article."*

The superiority of open-hearth steel for gun material, the enormous cost of his guns, and the secrecy observed, even in the case of inspectors of "war material on order," have influenced many foreign governments to cease giving orders to Mr. Krupp, and Italy and China appear, at present, to be the only powers that are making any very great demand upon the resources of Mr. Krupp's great establishment at Essen.

* Gun Foundry Board Report.



PLAN OF KRUPP'S FIRING-GROUND AT MEPPEN.

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* Gun Foundry Board Report.

V.

RUSSIA.

Sources of Supply and Condition of Artillery.

The very polite attentions always offered in Russia to the citizens of the United States, were renewed on the occasion of the visit to St. Petersburg of the Committee of the Gun Foundry Board, and the representatives of the various branches of the Government were untiring in their arrangements to make the Committee's visit most profitable and enjoyable.

SOURCES FROM WHICH THE ARMAMENT OF RUSSIA IS SUPPLIED.

"The Government of Russia has been an extensive purchaser of cannon from Mr. Krupp, at Essen; but, after adopting the Krupp gun for its armament, it proceeded to manufacture on that system for its own uses.

The course pursued to produce a supply from home manufacture was that of joint action between the Government and a private firm. The large steel works of Aboukhoff, near St. Petersburg, was the establishment with which the Government entered into partnership, becoming the owner of one-third of the stock. The Government is represented in the board of directors, the works are in the hands of the Minister of Marine, and Admiral Kolokoltzoff is the chief administrator or superintendent. At the commencement of the joint action, the Government contributed largely to increase the plant by providing tools suitable for its work, and very substantial aid has been provided from time to time.

The substance of this statement was collected from parties with whom intercourse was held, who did not, in distinct words, condemn the practice under which the Government has been acting since it commenced to manufacture its own guns, but they evidently held the idea that the condition of affairs would be much improved if the Government had absolute control of the works. In order to achieve this object it was understood that the Government is soon to acquire such

additional stock as will make it owner of about two-thirds of the whole. When this shall be accomplished, it is thought that the Government will be able to produce its guns at less expense than is now incurred.

It was freely admitted that the material produced under this system of joint action has been at great cost, but the Government has reconciled itself by the conviction that the product was of first-class quality and better than could be procured from other sources at less expense. The ground is taken that, in a matter so important as armament, high price is not to be considered an obstacle to the possession of the best guns that can be produced, and the authorities believe they have attained this object in their manufacture.

This experience of the Russian Government in its joint action with the Aboukhoff Steel Works bears directly upon one of the most important points that the Board is required to consider, viz., "any other method" apart from a Government foundry, pure and simple, by which cannon can be provided; and the results above cited demonstrate that in this combination in Russia, as in that between the English Government and the Elswick Ordnance Company, the Government must always expect to bear the loss.

The acquisition of additional stock may give the Government such control in the direction of the business of the works as to smooth the way to its possession of the whole. This seems to be the natural conclusion of the process now in operation, and its consummation would be a declaration of the practical failure of the plan inaugurated at the commencement. The experience of joint action between the Government and a private firm in Russia does not encourage the experiment in our own country.

Nearly the entire production of steel for cannon is distributed between the Aboukhoff Steel Works and the Kama, near Perm (in the Ural Mountains), but the product of the former is the more considerable. Among others, the Iznoskof and Alexandroff private steel works (both near St. Petersburg) manufacture projectiles, and as the Government diminishes its contracts abroad, they will develop their plants to meet the demands for gun material."*

* Gun Foundry Board Report.

The London *Engineering* of October 27, 1882, gave the following notice of the Alexandroff Steel Works:

These works were commenced at the end of 1877, commenced business in March, 1879, and since that time have been in continuous operation. The products are steel rails for the Government lines, and projectiles and guns of cast-steel, these latter being made according to the Terrenoire process. The plant comprises seven melting and six preparatory heating Siemens furnaces, which are arranged in a single line about 350 ft. long; the heating and melting furnaces alternate with each other. Six of the melting furnaces are of seven tons capacity, whilst the seventh takes a 9-ton charge. The latter is a little over 3 ft. larger than the smaller ones, and has two openings instead of only one on the working side. The gas-producers are placed in a line parallel to the furnaces, there being four to a melting and three to a heating furnace, and each pair of furnaces has its own chimney. The capacity of the four regenerator chambers under each melting furnace is 1539 cubic feet, and as the consumption of coal is about nine tons daily per furnace, the capacity per ton of coal per day is about 170 cubic feet. The hearth bottom of the melting furnaces, which are carried upon 2-in. cast-iron plates, are made of a lower layer of Dinas bricks 2½ in., covered by 7 in. of a mass formed of 42.5 per cent of clean sand from Lake Ladoga, 42.5 per cent of burnt quartz, and 15 per cent of Russian fire-clay; the sides and roofs are of Dinas bricks. The average working life of the furnace is 232 charges, the highest attained being 280. The roof requires partial renewal after about 150 charges.

> "**Russian Artillery Gun Factory.**—Although the amount of field artillery and siege pieces in the possession of the Government is very large, the work of manufacture is actively progressing, and the Russian Artillery Gun Factory in St. Petersburg is constantly occupied in the construction of guns up to and including the 8-inch, and rifled mortars of 9-inch caliber. This factory is well supplied with tools, has a capacity to turn out 70 field-guns per month, and is rapidly replacing the older models on hand." *

Most of the tools are of English manufacture, or are Russian duplicates of same.

Guns are finished and sighted here. The work of inserting lining-tubes is carried on with small field-pieces, the bodies of which are steel in one piece, except the trunnion-hoop, which is shrunk on in the usual manner.

An excellent plant still exists for the manufacture of bronze and cast-iron guns.

* Gun Foundry Board Report.

The steel parts to be machined and assembled are received from Aboukhoff and Perm, and, although this arsenal is well equipped,

> "its plant is not equal to all the work demanded of it. The deficiencies are supplemented by the Aboukhoff Works.
>
> **Aboukhoff Works.**—The Aboukhoff Works, which include the manufacture of steel on a large scale and the fabrication of cannon of all calibers, both for the army and navy, are situated in the alluvial basin of the Neva River, where good foundations are to be had only at great expense. The excavation for the 50-ton hammer was carried down 50 feet before moderately hard bottom (gravel) was reached. This cause has added largely to the general cost of construction of the works.
>
> The shops are extensive and numerous, but as they have been erected as needed, without regard to any general plan, they furnish no guide for constructing a new establishment. The largest gun-shop is 700 feet long and 70 feet wide, with the tools disposed longitudinally. The severity of the climate has rendered it necessary to ceil overhead with wood, and from this cause the shop is not so well lighted as is usual in Europe. The plant is of good quality and is being extensively developed. In the foundry, advantage has been taken of the undulations of the ground to place the forge at a lower level than the furnaces, thus conveniently providing for the transportation of the hot ingots by railway direct from the bottom of the casting-pit to the hammers. The capacity for casting reaches from 40 to 50 tons, requiring 1200 crucibles." *

Like many of the great steel-works of Europe, this establishment is in a transition state, extensive preparation having been made for the erection of a new steel plant and the introduction of different machinery and tools. There are three Siemens furnaces; two of 10 tons and one of 5 tons capacity; also two 5-ton Bessemer converters. In the re-heating furnaces, gas is employed.

The following extract is from a translation by Captain C. S. Smith and Lieutenant Rogers Birnie, U. S. A., of "The Fabrication of Cannon in Russia," by Lieutenant Michael Levitsky, Russian Navy, published in "Notes on the Construction of Ordnance, No. 21," May 14, 1883:

* Gun Foundry Board Report.

To-day the Aboukhoff works are in the hands of the Minister of the Navy, by whom they are administered through the intermedium of two superior officers, Captain Kolokoltzoff of the navy, chief administrator, and Robert Musselius, Major General of the Naval Artillery Corps, who is charged especially with the direction of the technical work. Since the date of its foundation this establishment has undergone a very considerable extension ; at present it covers an area of more than 300,000 square metres, and is possessed of 14 steam-engines of from 7 to 160 horse-power, forming a total force of nearly 550 horse-power, without counting 4 locomotives of a total of 50 horse-power. For the working of metals there are 170 different machines ; 6 puddling furnaces ; 16 ordinary forging furnaces ; 2 Siemens gas-furnaces ; 240 furnaces for casting steel, each of which has a capacity for 4 crucibles and is heated by means of coke ; 12 Siemens gas-furnaces having each a capacity for 24 crucibles ; a furnace for casting Siemens-Martin steel ; 2 Bessemer converters, and 10 steam-hammers, distinguished in respect to weight as follows :

Two of	about	1	ton,
Two of	"	2	tons,
One of	"	3½	"
Three of	"	5	"
One of	"	15	"
One of	"	50	"

Furthermore, the works possess a chemical laboratory for the analysis of metals and the raw material ; a physical laboratory for the mechanical tests of steel ; a gas-works furnished with six retorts, which supply light to the works at an annual consumption of 2,523,400 lbs. of coal. To provide against fire, there is available a steam-pump of 25 horse-power. The *personnel* of the works consists of 30 engineers and specialists and some 1200 workmen ; its annual production amounts to nearly 6,600,000 lbs. of steel, obtained by different processes and designed for different purposes : for the Aboukhoff works are not confined to the fabrication of cannon alone—that is only their principal specialty. They manufacture projectiles, locomotive tires, wagon-wheels and axles, and also shafting for marine steam-engines.

The steel prepared by these works is obtained by several different processes, as has been said above, but the process that gives the most satisfactory results consists in melting in crucibles a mixture, in definite proportions, of puddled steel, magnetic ore, wrought-iron blooms, and peroxide of manganese. By this mixture there is obtained a metal that is always perfectly homogeneous, and that can, at pleasure, be made hard and tenacious or ductile and malleable, according to the use to which it is to be applied. But the quality that particularly distinguishes the Aboukhoff cast-steel is its aptitude to welding, a quality that leaves too much to be desired, as is well known, in all other kinds of steel.

The puddled steel employed at the Aboukhoff works is in part furnished from the steel works of Finland (Arpe & Poutiloff), or from the Ural (Satkin, Youresan and Serebriansk), but by far the greater part is fabricated in the establishment itself, from the cast-irons of Arpe, Satkin, Youresan, Goroblago-

dat, Neviansk. The annual quantity of puddled steel furnished by these works amounts to nearly 4,400,000 pounds.

In casting a piece of considerable volume, like a cannon, the operation is commenced by placing a number of crucibles in each furnace, calculating their number from the ingots of metal necessary to fill the mould : the operation should, of course, be so conducted that all the crucibles may come to the melting point at the same time. The cast-iron moulds employed for casting small pieces have very nearly the same form as the finished pieces themselves. It is not the same, however, with cannon moulds. The first form of a gun is nearly cylindrical, the interior walls of the mould being only slightly conical, from the summit to the base, in order to facilitate the withdrawing of the piece. The relation of the area of each section of the ingot to that of each section of the finished gun varies usually from 2 to 3. Previous to casting, the mould is heated by filling it with red-hot embers ; the interior walls are rubbed with plumbago, or coated with white-wash or white clay, in order to render the surfaces smooth.

In castings of small dimensions the steel is turned directly into the mould from two crucibles, at first as rapidly as possible, afterwards slowly, but always continuously. For large cannon, such as 12-inch guns, which weigh more than 85,800 lbs., the steel from the crucibles is run at first into a pool, whence it afterwards flows in a continuous stream into the mould ; after the mould is filled, it is closed with a cast-iron cover loaded with weights, the pressure of which contributes to the production of a finer texture in the metal and a more compact grain. Sometimes, in order to effect a more uniform cooling, the free surface of the metal is covered with powdered and sifted clay, which evidently acts to retard the cooling of the upper layers, which, if not checked, often proves injurious to the homogeneity of the metal. The operation of cooling the ingot for a large cannon requires ordinarily from 23 to 25 minutes.

After the ingot has cooled, it is withdrawn from the mould and subjected to the action of the hammer.

Cannon of 8, 9, 11, and 12 inches, and generally all masses weighing from 28,000 to 96,000 lbs., are placed under the great 50-ton Nasmyth hammer ; for the hammering of masses embraced between 24,000 and 28,000 lbs., such as 6 and 6.03-inch guns, a Morrison hammer of from 3 to 5 tons is used.

For moving the pieces while being hammered, on each side of the great hammer are established steam cranes, the axes of revolutions of which are so disposed that part of the circle described by the point of surface of each crane passes by the median plane of the hammer and by that of the doors of the two Siemens re-heating furnaces. These furnaces are remarkable for their great size and in having a movable sole. Their chief merit lies in the facility with which it is practicable to regulate the intensity of the flames in attaining the desired degree of heat, being very much superior in this respect to the re-heating furnaces of the old system.

After the cannon has received under the hammer the desired form, it is removed to an ordinary lathe for rough-turning ; from the rear extremity of the breech, a disk is cut off to be used in the mechanical tests of the metal. The

operations of boring the cylinder and finishing the bore and chamber are performed in a single lathe, the cutting tools only being changed.

The next operation consists in making a hole through the extremity of the chase in the prolongation of a diameter of the bore, which is intended to receive a bolt, by means of which the piece is suspended during the subsequent operations of heating, tempering in oil, and annealing.

After tempering and annealing, the piece is hooped, which is one of the most important operations in the present construction of guns. The hoops are forged from disks or round slabs of cast-steel, which are cut in proper thicknesses from larger castings. A central orifice is first punched in each slab, and this is afterwards enlarged by introducing successively larger mandrels. The hoops are heated in an ordinary furnace before each mandrel is forced in: when the desired dimensions have been attained, the hoops are imbedded in a heap of fine charcoal and left there until cool. They are then faced and turned to dimensions in a lathe, tempered in oil, annealed, and finally carefully polished on the interior.

To assemble the hoops, they are first heated in a wood fire built upon the ground, and then plunged in a bath of melted lead until they are sufficiently expanded to pass over the body of the piece arranged in a vertical position. Each ring when heated is raised by means of a crane and cleaned on the interior to rid it of ashes, dust, etc., and finally passed over the chase of the gun. A few blows of a hammer cause it to descend to the position desired. In order that the gun may not be heated too much by contact with the rings, a current of cold water is passed into the bore, which enters at the muzzle and is emitted through a nozzle fixed at the same part of the gun.

After the hooping, the gun is again placed in a lathe and turned on the exterior to its proper outline.

When several layers of hoops are required, they are assembled in the same way. But care is taken to place the rings so that they " break joints " with the layer beneath.

CONDITION OF STEEL MANUFACTURE.

" There can be no question as to the character of the ore from which the metal used for cannon in Russia is produced. The Russian mines, from which much of it is obtained, are situated in the Ural Mountains on the border of Siberia. The ore is smelted with charcoal, and the iron is fully equal to the famed iron of Sweden. It is received at the Aboukhoff Works in the form of cast and wrought-iron. Use is also made of the best Swedish and Spanish iron.

The puddled steel, which is the basis of the Russian gun-metal, is prepared at Perm and at the Aboukhoff Works. The steel for casting all gun-tubes, jackets, and large hoops is prepared in crucibles. A portion of the magnetic ore, which

is found in the Ural, is one of the elements introduced into the crucibles and is said to have a beneficial effect upon the mixture.

Hoops for some small guns are made of Bessemer steel, the charge being selected from the best Ural and Swedish ores. The Siemens-Martin process is restricted to the manufacture of small ingots, being regarded with much less favor than crucible castings.

The most important improvement which has recently been introduced is Sir Joseph Whitworth's system of liquid compression. The advantages of this press have been alluded to in a former part of this report and need not be again recited. At the Aboukhoff Works, the effect of liquid compression is considered as very beneficial, and the impression was received that the system of forging by the press would also have been adopted if there had not already been established at the works one of the largest and most expensive hammers in the world, the tup of which weighs 50 tons, with a fall of 12 feet." *

The construction of its foundation was very difficult and expensive. In consequence of the uncertainty of the bed, the hammer has been fitted with a peculiar arrangement of guides, and the tup is not rigidly connected with the piston.

PRESENT CONDITION OF RUSSIAN ARTILLERY.

" The heavy ordnance for naval and sea-coast defence is designed to give velocities from 1700 to 1800 feet; but experiments to gain an increase, by lengthening the bore, are in progress. The following are the principal calibers:

12-inch 40-ton guns, 20 calibers long, are adopted for arming the Peter the Great and the Popoff—one, 30 calibers in length, weighing 50 tons, and burning 390 pounds of powder, is now under trial.

11-inch 27-ton guns, 22 calibers long, are used in several turret ships and in sea-coast batteries. The tube requires a 30-ton ingot.

There are also many naval 9-inch, 8-inch, and 6-inch guns about 22 calibers long, in service; but the models will soon be modified by increasing the length. For land fortresses the

* Gun Foundry Board Report.

6-inch gun is the prevailing type. Most siege guns on hand are of bronze, but a new steel pattern will be adopted for future fabrication. A recent accident gave a severe test to the system of construction adopted for Russian artillery. In experimenting with gun-cotton for use in shells, one of the latter, containing 40 pounds, exploded in the chamber of an 11-inch gun when the charge of gunpowder (128 pounds) was fired. The rear part of the breech was blown off at the weak point of the Krupp system. The trunnion-band was broken, throwing off a fragment; and *the diameter of the chamber was enlarged* 1 *inch.* The admirable quality of the metal, and the good adjustment of the strength of the several parts, is evident from this statement.

In testing steel, no value is attached to the ultimate breaking stress or percentage of elongation; and the computations are all based on the elastic limit, which is determined by noting where the increasing stresses and elongations cease to be proportional. This must never occur below 2400 atmospheres (16 tons per square inch).

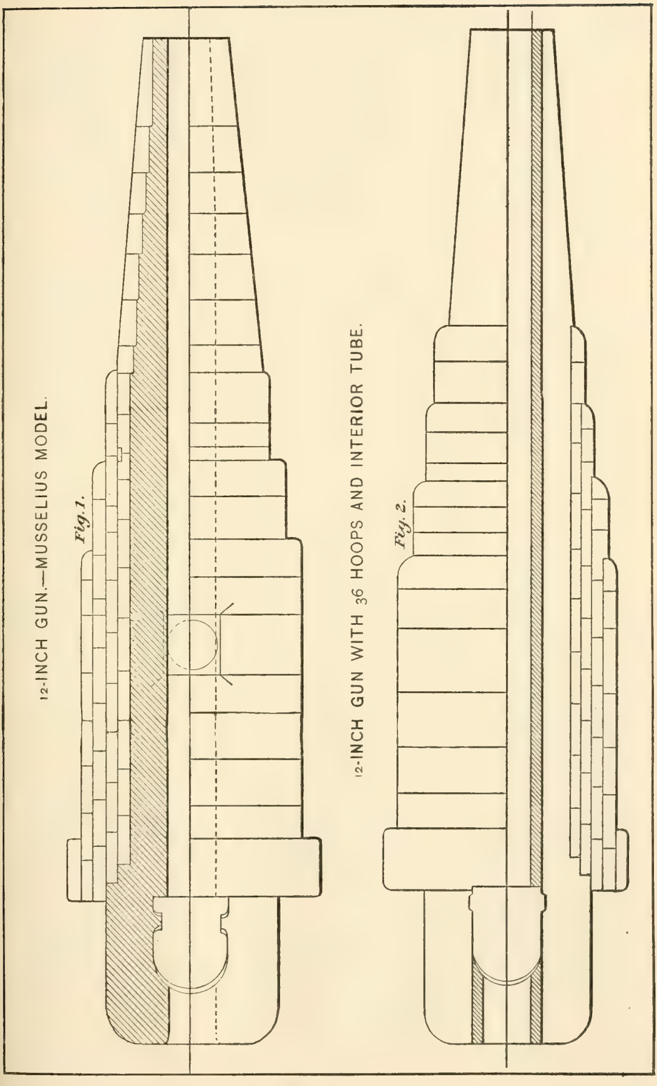
Construction.—All field-guns are of steel, and are mounted on a carriage fitted with rubber buffers to reduce the shock."*

The greater part of the steel guns of models before 1877 were purchased of Mr. Krupp and are similar to the German guns of same caliber. At Aboukhoff, for heavy guns, the first row of hoops has been extended to the muzzle (figure 1, Plate LXIX.) These hoops, of truncated form on the exterior, are of cylindrical form on the interior and are graduated along the chase.

"The special novelty of the Russian ordnance is a thin steel lining-tube, designed to receive the wear in firing and to be renewed when needful, without the expense and difficulty of re-tubing. This system is adopted for all calibers from the smallest up to the 12-inch gun, inclusive (figure 2, Plate LXIX.) The operation of inserting one of these lining-tubes in a field-gun was witnessed at Aboukhoff. The difference of their diameters was very small. The fitting of the slightly conical surfaces by measurement before insertion was done with precision.

When ready for insertion, the lining-tube was lubricated and introduced by hand. It was forced by hand-levers until

* Gun Foundry Board Report.


12-INCH GUN.—MUSSELIUS MODEL.
Fig. 1.
12-INCH GUN WITH 36 HOOPS AND INTERIOR TUBE.
Fig. 2.

> the end was nearly flush with the breech; hydraulic power then applied by a hand-pump was gradually increased to a pressure of 180 atmospheres, although no motion was apparent after it had reached 100 atmospheres. The rear end of the lining-tube forms the recess for the Broadwell ring." *

The following in regard to this process is taken from *Mémoires Mil. et Scientifique, Dept. de la Marine, Française, Vol. IV.*, and was published in "Notes on Construction of Ordnance, No. 21," May 14, 1883:

In this system the bore is formed of a steel tube independent of the body of the gun and extending the whole length from the face of the muzzle to the face of the breech . . . . The first experiments were made with a 9-inch gun; the work was done at Aboukhoff. This gun had already been fired 765 rounds with charges of prismatic powder varying from 27 to 46.86 pounds. It was re-bored and fitted with a steel tube in accordance with the plans of Messrs. Kolokoltzoff and Musselius. After the conversion, it was fired 455 rounds with a projectile weighing 261.36 pounds and the following charges of prismatic powder:

1 round with a charge of 27.06 pounds.
1 round with a charge of 31.46 pounds.
1 round with a charge of 35.86 pounds.
2 rounds with a charge of 40.48 pounds.
50 rounds with a charge of 23.32 pounds.
400 rounds with a charge of 46.86 pounds.

The mean of the pressures taken for ten rounds with a charge of 46.86 pounds amounted to 39,139 pounds per square inch; the maximum pressure was 41,850, and the minimum, 35,219 pounds per square inch.

At the end of this firing, very decided erosions were apparent in the chamber and about the junction of the chamber and bore; but the rifled part of the tube remained intact.

The artillery committee concluded that these results were satisfactory and that the system was good. The trials, therefore, will be continued, and will eventuate probably in the adoption, in Russia, of a system of tubed guns.

The following details of the conversion were submitted to the committee by the director of the Aboukhoff foundry. The thickness of the walls of the tube at the breech is about 1.496 inches and at the chase about 1.26 inches; the tube is turned on the exterior to the form of truncated cones of different diameters, separated from each other by a shoulder and having their larger bases turned towards the breech.

The exterior diameters of the tube corresponding to the breech of the gun are respectively 12.417 and 12.39 inches; in the portion within the chase the greater diameter is 11.52 inches and the smaller 11.41 inches. The exterior diameters of the tube at the several cross-sections of the gun are *nearly* equal

* Gun Foundry Board Report.

to the corresponding interior diameters of the body of the piece, except that about the base of the chamber the exterior diameters of the tube are 0.03 of an inch greater than those of the body; at this part there is, consequently, a tension.

In order to introduce the tube into the bore the following total pressures were employed:

Total pressures exerted.	Corresponding lengths of tube "forced in."
7.3 tons	12.0 inches.
14.6 "	10.0 "
22.0 "	8.5 "
29.2 "	8.0 "
32.8 "	7.0 "
35.8 "	6.89 "
42.3 "	6.00 "
50.0 "	5.00 "
57.0 "	4.00 "
60.6 "	3.78 "
70.0 "	2.78 "
84.0 "	1.50 "
100.0 "	0.756 "
125.0 "	0.374 "
Final pressure, 184.0 "	...

After the firing, the tube was extracted from the gun by a series of pressures, respectively, of 250 tons, 144.7 tons, 96.5 tons, and 48.5 tons.

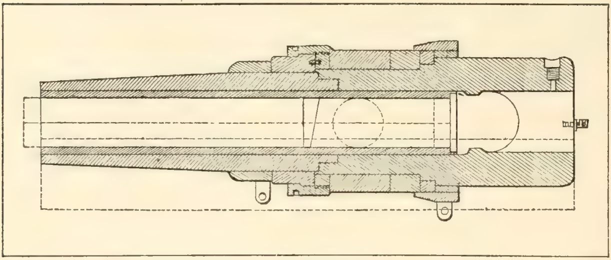
The same tube was again introduced into the bore by a series of pressures concluding as follows: 38.6, 57.9, 77.5, 96.5, 115.8, 144.0, 175, and 198 tons.

The last figures show that the exterior diameters of the tube were not materially enlarged by the firing, since the force required to make it re-enter the bore was nearly the same before and after the firing of the 455 rounds.

> "The Russian officers claim that these tubes can be renewed in the field, and cited instances of two 9-inch mortars, weighing 5½ tons each, needed for use on the Danube during the late war. Being too heavy for the available means of transportation, they were forwarded in three pieces—a tube, a breech-jacket, and a muzzle-jacket. The two latter were screwed together, and the tube was inserted by a jack on the spot; both mortars did excellent service."*

The fabrication of cannon with lining-tubes most naturally led to the system of dismountable pieces; and the 9-inch mortars were constructed on the same principle as the 8-inch dismountable cannon. To mount these, the breech-jacket is placed upon the carriage; the

* Gun Foundry Board Report.



9-INCH MORTAR DISMOUNTABLE.—$\frac{1}{20}$.

muzzle-jacket is then raised into place, and the strengthening hoops screwed on. The lining-tube is then forced in, a long screw, with plates taking against the faces of the breech, and muzzle ends, being employed to force all the parts into position. To dismount, the screw is turned end for end. Twenty men will assemble an 8-inch cannon in about three hours.

"Sheets of recent unpublished experiments were exhibited, showing the locus of the varying pressure in the bore of a long 4.2-inch gun. These pressures were measured by Rodman gauges in the usual way, special care being taken to place the part acted upon by the gas nearly flush with the bore. The results thus far have proved quite accordant and very interesting, indicating that as the distance from the bottom of the bore increases, the pressures at first decrease a little, and then rapidly increase to a maximum at a point slightly in rear of that originally occupied by the front band of the projectile. Here the pressure is nearly double that at the bottom of the bore, and evidently is increased by the reaction from the shot at the instant of taking the grooves. This investigation has much importance in connection with the problem of the best form and dimensions for the powder chamber. The experiments are to be continued with a 16-inch 80-ton steel gun made at Aboukhoff and fitted for this purpose. It is 22 calibers long and constructed in the following manner, viz.: tube in one piece; jacket in three parts extending to muzzle; four layers of hoops and a fifth hoop over the breech. It is pierced at various points to receive the gauges.

An experimental 11-inch 47-ton all-steel gun, 35 calibers long, consisting of tube, jacket in two parts extending to muzzle, and three layers of tapering hoops, was ready for trial.

Breech-Loading.—Russia has adopted the Krupp breech-loading system with slight modifications for all calibers, but a few guns fitted with the French interrupted screw were noted. Steel alone is used for new fabrications."*

All the guns of the new models are fitted with the cylindro-prismatic wedge, similar to the German guns, and in the model of 1877, manufactured at Aboukhoff, the loading-cylinder has been abolished. There are some 11-inch coast guns bearing the French screw fermeture, and a few mountain guns have been fitted with the de Bange fermeture.

The *gas-check* is an unmodified Broadwell ring.

Chamber and Rifling.—For all guns of model 1877, firing projectiles with copper ring, the chamber is composed of two cylindrical parts, the powder-chamber and the projectile-chamber, connected with each other, and with the bore by truncated cones. The rifling extends into the projectile-chamber, but not into the cone of the powder chamber, and is increasing. For guns of old models the rifling is similar to that of the German guns and not increasing. In the larger calibers the chamber is eccentric. The rifling in a number of the guns of 6, 8, 9, and 11-inch caliber has been modified to admit of firing projectiles with copper bands instead of the old projectiles, which were enveloped in lead.

The gun-carriages, designed by Gunnery Lieutenant Razkazoff, Russian Navy, and Mr. Anderson, for the 12-inch 40-ton guns of the Popoff, are constructed on the principle of Major Moncrieff, and combine arrangements and improvements involving simplicity, compactness, and strength.

The carriage consists of two pairs of parallel armor-plates, six inches thick, corresponding to the brackets of an ordinary gun-carriage. They are connected in front by steel castings of triangular shape, in the rear by iron plates and angle brackets, and in the middle by two cast-steel buffer-boxes and by a central socket-piece, which fits on to a pivot fixed to the deck of the turret, and about which the platform, so arranged, revolves. The carriage brackets form the main frame of the revolving platform, which has no rollers, but is simply carried up and slides on a turned wrought-iron ring, which gives better support and sufficient freedom of motion. In order further to strengthen the platform,

* Gun Foundry Board Report.

as well as to provide means of turning it, a heavy cast-steel ring, forming a bevel-wheel, is fixed underneath, and is turned by a steel pinion, the shaft of which is actuated by a 40-horse-power double-cylinder engine placed on the main deck nearly under the turret.

Through the front of the brackets, two rocking-shafts are placed, and carry on their extremities pairs of rocking-arms, on the outer ends of which the guns are supported by their trunnions. To the rear ends of the brackets, hydraulic cylinders are fixed, two for each gun. They are connected in pairs by pipes, so as to act simultaneously. The plungers, or rams, of the cylinders are connected to the rocking-arms by means of heavy connecting-rods, so that when these plungers are driven out, they turn the arms, raising the guns to the firing position, at which point the arms rest against buffers fixed on the front part of the platform.

In this position the arms supporting the guns come within only a few degrees of the vertical, so that when the water is allowed to escape from the cylinders, the plungers will be driven in by the weight of the gun, which will thus descend to its loading position, where it rests on the central buffers. This is only possible with hollow-trunk cylinders, the connecting-rods of which abut against the bottoms of plungers at their lower ends, forming a ball-and-socket joint, by which means all guides are avoided, and with them the complicated arrangements of the turn-table.

The breech end of the gun is supported by a pair of radius bars which steady it and determine the path of the gun in moving from the loading to the firing position, and the reverse.

The elevation and depression are also given by means of these bars, the lower ends of which are jointed to the studs of two sets of elevating gear that are fixed on the outer faces of the brackets, and are worked by one handle common to each pair. Each elevating arrangement consists of a screw working through a nut, having a stud on it for receiving the lower end of the radius bar, so that when the screw is turned, the nut travels up and down and moves the lower end of the bar.

The elevating screws are so attached to the brackets that when the gun is up, the motion of the nuts connected to the lower ends of the radius bars produces nearly the same amount of motion to the breech of the gun, thus varying its elevation; but when the gun is in the loading position, the motion of the lower ends of the bars does not cause any sensible motion to the breech, so that when the gun is down, the elevation or depression can be changed without moving it; the gun will assume its proper elevation as it rises into the firing position; and, again, if the gun is fixed with any angle of elevation, it will also come to the same loading position.

For raising the guns, water is used under a pressure of about 600 pounds per square inch, supplied by a small duplex pump and stored in an accumulator. The water from the pump passes through the central pivot of the platform, and is then distributed to the four cylinders. The arrangement for transmitting the water through the center of the revolving platform consists of a stationary pipe in the center of the pivot, made hollow for the purpose, and is surrounded by a massive gun-metal chamber fixed to the platform and revolving with it.

The water under pressure flows through the center pipe, and the waste escapes by the hollow pivot. A branch from the pivot pipe leads to a pair of balanced valves that distribute the water to the cylinders so that each gun can be raised and lowered by the motion of one hand-lever. The guns can be stopped in any position and lowered gently at pleasure. Each hand-lever is connected to the ram of the cylinder by means of a rod, so that the water is automatically shut off when the gun reaches its highest position.

To start the gun, a pressure of over 600 pounds per square inch is required, and, as the accumulator produces an almost constant pressure of that amount, there will be a large access of power towards the end of the stroke, which will enable the gun to be raised with any required velocity.

The hand-valve is controlled automatically in both directions by the motion of the gun. Therefore there is no danger to be feared from inattentive operators, for, provided there is a constant pressure in the accumulator, the gun will always take the same time to reach its firing position.

The chief novelty and most important detail introduced is the means of absorbing the recoil. It consists of a valve-box, which is placed in the middle of the pipe, connecting a pair of cylinders. Through this valve-box is passed a long valve spindle, having at one end an ordinary conical valve, by which the outlet of the box is closed. The other end is supported by a guide in which it is free to slide to the extent to which the valve is to open. On the valve spindle are threaded a number of dished springs, which are confined between a disk held in place on the spindle by an adjusting nut, and a crosshead which slides freely on the spindle, and is connected by its ends through a pair of chains to the rocking-shaft carrying the gun. The springs have initial pressure given them by the adjusting-nut on the spindle, and close the valve just sufficiently to support the gun in its firing position ; but, as soon as the gun begins to fall, the rocking-shaft on which the arms are keyed turns and winds the chains, which draw up the crosshead, and thus further compress the springs as the gun descends, thus adding automatically any required increase of load on the discharge valve, and therefore any required increase of resistance in the cylinders to take up the force of recoil.

To meet any want of uniformity in the compression of the springs, or to produce any variations in the resistance to the recoil, there are cam-pieces on the shaft over which the chains are laid. These are so shaped as to produce a changeable rate of winding the chains, and therefore a corresponding change in the increase of load on the valve. The action of this mechanism is automatic, depending only upon the motion of the gun.

The spring disks are slightly conical, and so tempered and shaped that when compressed to their limit of elasticity they become flat, and then resist compression as a solid steel cylinder.

The water from the cylinders during recoil, as well as while lowering the gun without firing, is discharged into a long tank, by which both the discharge-valves and the hand-valves are surrounded. This arrangement renders long and large exhaust-pipes unnecessary.

A friction-clutch prevents the recoil from revolving the platform. The handle for giving motion to the platform, whose connecting-rod passes to the

engine through the pivot, is situated close to the handle for raising and lowering the guns, so that the captain of the guns has at hand all the means for working them, being able to keep them constantly in the direction of the enemy while loading, and to raise them at the proper moment for firing.

The accumulator is loaded by permanent air-pressure as in an ordinary air vessel, but the difference is, that the compressed air is kept apart from the water in special tubes, which are placed in any convenient part of the ship. By this means, compressed air may be stored up in the tubes, and left ready for subsequent use, permitting several shots to be fired, in case of necessity, before steam is up. Another important advantage of this accumulator is that the initial pressure of air may be obtained without the use of an air-pump, by letting the water out of the water-vessel of the accumulator, allowing it to fill with air, and forcing the latter into the air-tubes by again pumping up the water-vessel. By repeating this operation, any degree of pressure may be obtained. By means of this accumulator, the gun can be worked independently of steam.

Experiments with these gun-carriages have been very successful, proving their convenience and rapid working.

> " The experiments with Russian artillery are made at the Polygon at Ochta, near St. Petersburg. The grounds afford a range of about 7 miles, and the establishment of the navy, under Admiral Kouprianoff, and of the army, under General Erme, are side by side, so that each service can always witness what is done by the other. A 12-inch 50-ton rifle, an 11-inch, and several smaller guns were in position at our visit."*

* Gun Foundry Board Report.

VI.

UNITED STATES.

Sources of Supply and Condition of Artillery.

The sources of supply at the present time appear to be limited to the Midvale Steel Company and the small ordnance machine-shops at the Navy Yard, Washington, D. C. The former has been able to supply steel parts for a few 6-inch breech-loading rifles, and is increasing the size of its plant for the manufacture of gun material. At the latter, steel guns of from 5 to 10-inch caliber are being fabricated. The heavier forgings for these guns have been supplied by foreign steel manufacturers.

SOURCES FROM WHICH THE ARMAMENT OF THE UNITED STATES IS SUPPLIED.

"Previous to and during the civil war the armaments of the United States were supplied from—

The Cold Spring Foundry, West Point, N. Y.

The South Boston Iron Works, Boston, Mass.

The Fort Pitt Foundry, Pittsburgh, Pa.

The Reading Iron Works, Reading, Pa.

The Builders Iron Foundry, Providence, R. I.

The Phœnix Iron Company, Phœnixville, Pa.

The Ames Manufacturing Company, Chicopee, Mass.

Since the termination of the war the Fort Pitt Foundry has ceased to exist. The South Boston Iron Works Company has manufactured a few experimental guns, and with the West Point Foundry has executed some small orders of the Government in the conversion of cast-iron smooth-bores into rifle guns by inserting and rifling a coiled wrought-iron tube.

None of the companies mentioned above have ever made steel guns, and virtually the United States is destitute of a source from which such an armament as the age demands can be supplied." *

* Gun Foundry Board Report.

This is further proved by the following correspondence presented to the Board, after its return from Europe, by the two companies that have asked Government aid. The amount required and asked for is so nearly equal to the Board's estimate of the approximate cost of a gun-factory plant entire, that this fact alone would indicate that they have no plant for the fabrication of *modern steel* guns.

South Boston Iron Works,
Boston, January 16, 1884.

Commodore E. Simpson, U. S. N.,
President Gun Foundry Board, Philadelphia.

Sir: Referring to your communication of May 1, 1883, inviting me to revise my proposition of January, 1882, referred to, and so modify it as to state what aid I should require of the Government to enable me to so enlarge our present plant as to be suitable for the manufacture of the heaviest ordnance required for modern warfare from the crude material, I now beg to say I have considered the problem carefully, and conclude that the subject is so important and comprehensive—so much depending upon information obtainable only in Europe, and of which I have obtained very little, compared with that in possession of your Board—I had better confine my estimates in reply to that portion of the proposed plant of which I have some practical knowledge, and so have considered the cost of such additional machinery and tools as would, with our present plant, enable us to machine-finish, from the steel forgings or compressed ingots, modern steel guns at rates as follows:

Six guns of 16-inch caliber per year.
Twenty guns of 12-inch caliber per year.
Twenty guns of 10-inch caliber per year.
Thirty guns of 8-inch caliber per year.
Forty guns of 6-inch caliber per year.

I estimate the amount required to bring our plant up to this capacity would be $800,000, and require two years' time.

We desire to make this enlargement as soon as practicable, and ask the Government to advance the necessary money, under proper guards and restrictions, to be reimbursed to the Treasury when a reserve of 5 per cent of all the income from said machinery and tools shall amount to a sum sufficient. With a reasonable volume of business the Government would be repaid in full within ten years.

Should your Board recommend this method to be adopted for the manufacture of heavy ordnance, but wish to provide for a complete establishment capable of producing the steel from the casting of the ingots, as well as the machine-finishing of guns, I beg to refer you to my letter of January, 1882, referred to, and say I am ready to undertake the construction of the complete establishment upon the same terms as proposed for the machine department. In that event, I should expect to unite our works with that of the West Point

Foundry Association, and move to such locality as would be approved by the Government authorities.

Very respectfully, your obedient servants,

SOUTH BOSTON IRON WORKS,
By WM. P. HUNT, *President.*

WEST POINT FOUNDRY,
Cold Spring, January 18, 1884.

COMMODORE E. SIMPSON, U. S. N.,
Chairman of Gun Foundry Board, Philadelphia.

SIR: Referring to your communication of May 1, 1883, respecting a plant to manufacture ordnance, we beg leave to make the following reply, which, in consequence of the questions asked us not being sufficiently definite, is necessarily approximate in its character.

Our establishment in its present state is capable of finishing a limited number of steel breech-loading guns, but is inadequate to the wants of the Government. We would leave it as it is, using it to the extent of its capacity for ordnance, and making projectiles, gun carriages, &c. (for which it is well adapted), if required. We would then propose to build an entirely new plant, independent of the old one on our property, capable of turning out about 120 guns per year, ranging from 100 tons to 6-in. caliber or less, the necessary steel forgings to be furnished to us. We estimate the cost of such a plant, including buildings, engine and boilers, lathes, cranes, and other machinery, about $800,000.

As it would be impossible for us to procure the means to put up such a plant, the only plan which seems feasible to us is for the Government to advance the necessary amount under such conditions as may be deemed proper, and with a proviso for its ultimate repayment when 5 per cent of the amount of ordnance business done on said plant shall be equal to the sum advanced, the United States to remain proprietors of the plant until it is paid for as proposed.

With regard to the making of steel forgings, we understand that your Board has obtained in Europe the necessary information, and have more knowledge of the subject than we have been able to procure. We have, therefore, only to say that we should be willing to get up a plant on the terms proposed for the construction plant, should it be considered advisable by the United States to locate it on our property, or to combine it in the same establishment as that in which the ordnance is finished.

We estimate that it would require about two years to create the construction plant, but we are not prepared to state how long it would take to put up the plant for making the steel forgings.

Very respectfully, your obedient servants,

WEST POINT FOUNDRY ASSOCIATION,
G. PAULDING, *President.*

In these letters are also presented the opinions of these companies as to the proper means of providing modern ordnance.

CONDITION OF STEEL MANUFACTURE.

> "With a view to such experiments as their appropriations would justify, the Ordnance Bureaus of the War and Navy Departments have from time to time addressed the steel manufacturers of the country on the subject of furnishing steel for cannon, but thus far have met with only a partial success.
>
> The reasons for this will be noticed farther on in this report, but the fact is here stated to emphasize the conclusion that the immense steel works of the United States, from lack of demand for this special material, have not the necessary plant for forging, and are in no condition at present to manufacture steel for cannon in such quantities and in such sizes as are essential for a suitable armament for the country." *

In December, 1881, Lieutenant C. W. Whipple, U. S. A., prepared an interesting report (published in the "Report of the Getty Board on Heavy Ordnance and Projectiles—1882") on the steel manufacturing facilities in this country for gun-construction, and presented a list of the manufactories with their furnace and forging capacities to produce ingots of the proper weight for tubes and hoops. In this report, Lieutenant Whipple gives the heaviest hammer (that of Park, Brothers & Co., Pittsburgh, Pa.) a tup of 17 tons. "But with the steam it is computed at 67 tons." Nearly all European steel factors do not approve of the use of steam above, consequently the power of the heaviest hammer in this country may be recorded as 17 tons.

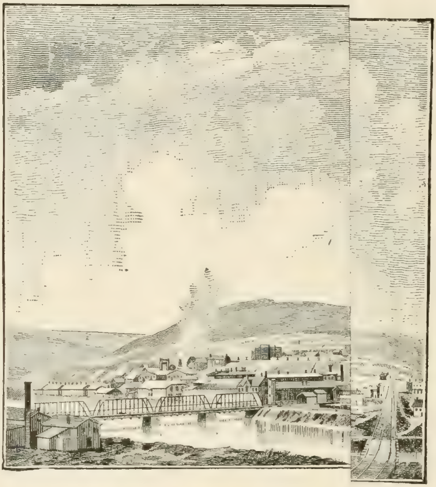
Since the preparation of the above report, open-hearth steel has been accepted by the majority of good authorities as the most uniform, and the development of open-hearth plants in the United States finds, at the present time, the

Cambria Iron Company, Johnstown, Pa.,
Midvale Steel Company, Nicetown, Philadelphia, Pa.,
Springfield Iron Company, Springfield, Ill.,

the best prepared to cast the required material.

Cambria Iron Company.—These works, by gradual development and acquisitions, have grown to be the most extensive of their kind in the United States. They comprise large coal and iron mines; eleven blast-furnaces; Bessemer and open-hearth steel works; extensive mills for puddling and rolling iron and steel rails of all weights and patterns, and many special forms of both iron and steel, including

* Gun Foundry Board Report.



←——————————————————————————→

COKE OVENS.

FURNACES
Nos. 1, 2, 3 & 4.

MACHINE

STABLES:

FOUNDRY.

BLACK

CAR SHOP

PATTERN SH

TIME OFFICES

steel-wire; machine, smith and boiler shops; foundry and other mechanical accessories, beside many important collateral industries.

The principal establishment (Plate LXX.) is situated at Johnstown, Cambria County, Pennsylvania, at the base of the western slope ot the Allegheny mountains (1184 feet above the sea), on the main line of the Pennsylvania Railroad, and 78 miles east of Pittsburgh. It is built in the deep level cutting at the junction of the Stoney Creek and Little Conemaugh River, which unite here and form the Conemaugh River. The works extend over an area of 60 acres, of which seven are covered by the rolling mills.

The occurrence of iron-ores in great variety and extent in the coal-measures at Johnstown and its vicinity having attracted attention to the region as a promising seat of iron manufacture, the working of the ores of Cambria County was begun as early as 1809, by the erection of a forge at Johnstown, which was subsequently removed to the Conemaugh River, where it was operated until about 1825. The Cambria Iron Company was organized. and obtained its first charter in 1852, at which time the property consisted of valuable and extensive tracts of mineral and timber land, and a number of blast-furnaces of rather primitive construction, situated at considerable distances from each other. In 1853, the construction of four coke furnaces was begun at Johnstown, but notwithstanding the great natural advantages offered by the situation, the operations of the Company were not successfully conducted. In 1855, the works having suspended, they were leased to Wood, Morrell & Co., who had become creditors. During the seven years' duration of the lease, notwithstanding the complete destruction of the rolling mill by fire in 1857, they developed the resources of the property, increased the capacity of the rolling mill to over 600 tons of iron rails per week (since increased five-fold), made many important improvements, and succeeded in establishing an extensive and profitable business. In 1862, on the termination of the lease, the Cambria Iron Company was re-organized, and the business since that time has been conducted in its name.

In 1868, the blast-furnace at Conemaugh, two miles east of Johnstown, was purchased, and about the same time, and under the name of the Blair Iron and Coal Company, four blast-furnaces, east of the Allegheny mountains, were added; one located at Bennington, one at Frankstown, and two at Hollidaysburgh.

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CAMBRIA IRON AND STEEL WORKS, JOHNSTOWN, PA

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Henrietta were purchased. In 1872, a large portion of the rolling mills was again destroyed by fire, but such were the resources and energy of the management, and the co-operation of the employees, that within one week after the fire, the machinery was again in operation under temporary shelter, which was replaced by brick and iron fire-proof buildings, without stopping the manufacture.

The Bessemer steel works commenced operations in 1872, and in 1873 the construction of blast-furnace No. 5 was begun at Johnstown, although it was not put in blast until 1876.

The buildings for the greater part are built of brick; some are constructed of iron frames with brick panels; nearly all have iron rafters covered with slate or corrugated sheet-iron.

Dimensions of the principal buildings, (Plate LXX.):

	Feet.		Feet.
Rolling Mills	87	×	1900
Bessemer Steel Works	105	×	165
Open-Hearth Steel Works	105	×	162
Blooming Mill	120	×	355
Blooming Mill annexes, each	55	×	75
Boiler and Producer Houses, one	56	×	330
Boiler and Producer Houses, one	56	×	250
Machine Shop	65	×	215
Machine Shop, two story annex	40	×	85
Smithery	70 octagon.		
Smithery, two wings, each	40	×	60
Foundry, one	75	×	145
Foundry, one	75	×	165
Roll Turning and Boiler Shops	110	×	315
Pattern Shops, 2 stories	55	×	110
Car and Carpenter Shops, 2 stories	60	×	140
Drawing Rooms, 3 stories	55	×	65

The *blast-furnaces* of the Cambria Company are located: six at Johnstown and one at East Conemaugh in Cambria county; one at Bennington, two at Hollidaysburgh, and one at Frankstown, all in Blair county. Those at Johnstown, Conemaugh, and Hollidaysburgh, No. 1, are the newest and largest. Their principal dimensions and average weekly output are given in the following table:

Furnace.	Height in Feet.	Diameter of Bosh, Feet.	Diameter Hearth, Ft. In.	Weekly Output, Tons.
Johnstown, No. 1	76	16	8 6	900
" No. 2	76	16	8 6	900
" No. 3	76	16	8 6	900
" No. 4	76	16	8 6	900
" No. 5	76	19	10 0	800
" No. 6	76	19	10 0	1125
Conemaugh	63	12	6 6	250
Hollidaysburgh, No. 1.	59	14	8 0	350

The other furnaces are of older date, averaging about 50 feet in height and 11 feet diameter of bosh.

The Johnstown furnaces Nos. 1, 2, 3, 4, forming together one complete plant, are at present (1884) being completely remodelled. Nos. 1 and 2 will go in blast during the summer, and Nos. 3 and 4 will follow about seven months later.

A full description of these furnaces, together with the *rolling*, *puddle*, and *wire-rod mills*, and *bolt works*, which are very extensive and well equipped, was published in "Iron," of March, 1884.

The *foundry* is a brick building 25 feet high, containing two Sellers improved steam-cranes of 25 tons capacity each, one 15-ton steam-crane, one 16-ton reverberatory air-furnace, and one 5 ft. cupola, with a capacity of 8 tons per hour. A brick addition, 30 feet high, with an iron roof, contains three 10-ton steam-cranes, one 5-ft. cupola of 8 tons capacity per hour, and one 30-inch cupola for chilled rolls and special heats. The largest casting made in the foundry weighed 35 tons. The average daily output of finished castings is 30 tons.

The *Bessemer plant* was the sixth started in the United States (July, 1871). While its general arrangement and many of its details were copied from drawings of the Troy, and Harrisburgh, works, and while it conforms in principle to the American type, there are many minor changes, some of which have been very generally copied. The first deviation from previous designs was to put the melting department and the converting section into the same building of equal height throughout. This gave the converting room ample height and ventilation.

The cupolas are five in number, 7 ft. 6 in. diameter of shell, with 6 ft. internal diameter above the tuyeres, and 5 ft. 4 in. diameter of bosh and hearth. The maximum height from the sand bottom to center of tuyeres is 3 feet. Each has six tuyeres of 6 in. diameter, through which blast is supplied from three Baker rotary pressure blowers, each driven directly by a Wilbraham engine, 16 in. x 24 in., at 110 revolutions per minute, and one No. 10 Sturtevant blower, furnishing to these and to four other *spiegel* cupolas, 33,000 cubic feet of blast per minute. The capacity of one cupola is 600 tons of iron and scrap melted at a continuous blast of 72 hours. The cupolas are located on either side of the main trough, into which they are tapped, and down which the melted metal is directed into either of two 10-ton ladles set on a hydraulic weighing platform, where it is stored until the converters are ready to receive it.

There are two vessels of 7½ tons capacity each, their product being distributed by a hydraulic ladle-crane. The Bessemer blowing-engines are independent and of peculiar construction. There are also two Worthington compound pressure-pumps, each with four plungers of 9½ in. diameter, 36 in. stroke. All of the pressure-pumps are connected with accumulators in the converting, blooming, and open-hearth departments, so that the pressure is constant and regular.

The Bessemer works are supplied with steam by a battery of nine 4 ft. tubular boilers of Matthew-Moore type, and eight 5-ft. plain horizontal tubular boilers. The best average, although not the very highest work done, in the Bessemer department, was 82 heats of 7½ tons each per 24 hours. The best weekly record reached 3700 tons of ingots, and the best monthly record, 16,000 tons. The best daily output was 670 tons.

Many grades of steel are made in the converters, from the softest wire and bridge-stock to spring-stock. All the special stock, that is, other than rail, is carefully analyzed at the company's *chemical laboratory*, heat by heat, and the physical properties are determined by a tension test made on a bar one inch square and measured on twelve inches. From the results thus obtained, the use to which it is to be applied is determined.

As a matter of interest, the fact may be mentioned, that the Cambria Company preserves as a relic the vessel in which Kelley endeavored to make steel in 1860. It has an external diameter of 38 inches, an interior diameter of 30 inches and a height of 4½ feet. The bottom was a perforated, unburned brick. The blast pressure was 5 pounds. For reasons that are now obvious, no malleable metal was produced.

The open-hearth plant consists of three Pernot revolving-hearth furnaces, fitted with all the recent improvements in roofs and ports, and also arranged in accordance with the principles which have made the American Bessemer works so much more productive and economical than those which preceded them. There are two 16-feet pans of 15 tons capacity each, and one 14½-feet pan of 12 tons capacity; each one is supplied with gas by four Siemens producers. A separate pit, with an independent hydraulic ladle-crane of twenty tons capacity, is located in front of each pan, and hydraulic cranes of smaller capacity, for delivering the ingots to train cars, are conveniently located. A Sellers steam-crane, of twenty-five tons capacity,

is also in use for special purposes. A large part of the product of this plant is made in special castings, for use in and about the mills, for custom work, such as engine-shafts, gearing rolls, bridge-castings, etc. The smaller pan is now run on the Krupp dephosphorization process. The product of the two 16-ft. furnaces reaches 25,000 tons a year.

In the *blooming-mill* the 40-in. blooming train, for blooming 18½-in. ingots, is driven by a reversing engine with two cylinders, 40 in. in diameter, 48 in. stroke, and is geared to the train, three to one, with engine speed at 90 revolutions per minute. The train is two-high. The tables on both sides of the train are operated by hydraulic cylinders, and the screws for controlling the height of the top roll, are actuated by the same power, through a cylinder and gearing on the top of the housings. One-half of the weight of the upper roll is borne on steelyards by counter-weights, and the balance of the power required to raise it is supplied by hydraulic cylinders at each housing. The ingots weigh 5000 pounds each, and are rolled into seven-inch blooms, each ingot making six to eight rails. Eight Siemens heating furnaces are used, having an aggregate capacity of sixty-six ingots. They are supplied with drawing and charging apparatus, which is driven by an 18 in. by 20 in. vertical engine, power being taken from a line shaft extending along the ends of the furnaces. Twenty Siemens and four Wilson's producers are used, steam blast being gradually substituted for natural draught throughout.

The new blooming train now being built will be 48 in., two-high, driven by a pair of horizontal reversing engines, 44-in. cylinders, 60-in. stroke, speed 60 revolutions per minute, geared, two to one, to the train. The rolls, which are of steel, cast in the open-hearth department, are 8 ft. long between necks, 44 in. diameter, cored 20 in. diameter through the body, weigh about sixteen tons. The weight of the upper roll is carried as before described, the adjustable screws being actuated by a small two-cylinder reversing engine. The tables are 8 ft. by 30 ft., and are driven by bevel gearing on the end of each roller, power being supplied by a horizontal engine, placed at one end of the table. A pair of hydraulic cylinders push the finished bloom sidewise to the delivery rollers which carry it to the hot shears. The shears are driven by a 14-in. by 24-in. vertical engine.

The foundations of the train and engines are constructed in a most substantial and durable manner, of cut stone, 12 ft. deep, laid upon a concrete bed 3 ft. deep. Both blooming trains are served by 25-ton

cranes for changing rolls, pinions, etc., besides the 4-ton hydraulic cranes for handling ingots. A Sellers 2½-ton, and Condie 5-ton steam-hammer are located conveniently near the trains.

Twelve soaking pits, of the Gjers type, are now in process of construction, being located within twenty feet of the 40-in. train. They are 21 in. square, 10 ft. deep below ground, covered by a hydraulic crane of 24-ft. jib. Hydraulic pressure is maintained by a Worthington compound duplex pump, 9½-in. plungers, 36-in. stroke, connected with accumulators giving 350 pounds pressure per square inch. The product of the 40-in. train for the past year reached 200,000 tons of ingots bloomed. Steam for the blooming mill and open-hearth plants is generated in twenty 48-in., and four 60-in. by 18-ft. tubular boilers.

The *roll-turning* department occupies the brick and iron building jointly with the *boiler* and *roof* shops. Ten lathes are set in line and are driven by an 18-in. x 20-in. vertical engine. The largest lathe will swing a 48-in.x 14-ft. blooming roll; the smallest is for wire-rod rolls of 7-in. diameter and 10 in. long. The heaviest rolls weigh 16 tons. The lathes are all served by a portable crane running on a narrow gauge track in front of them.

The *smithery* is a brick octagonal building, with a wooden trussed roof carried on a cast-iron column in the center; this forms a mast for a crane, which serves eight fires; four other cranes serve the remaining fires. There are two 1500-pound and one 2500-pound hammers. One wing serves as a store-room for iron and steel; another, 45 ft. x 60 ft., now being built on the opposite side of the octagon, will contain, when finished, a 2-ton steam-hammer, a large furnace, five single forges, and two 3-ton cranes.

The extension of the *machine-shop* is two stories in height; the lower story is used as a locomotive shop, and the upper, which is reached by an elevator, is employed for the manufacture of small tools, taps, dies, etc. It contains lathes, drill-presses, shapers, planer, gear-cutter, and oil-testing machinery, and is driven by an 8-in. diameter, 9-in. stroke, horizontal engine running at 200 revolutions per minute, which also furnishes power to the 3-ton elevator.

The main part of the shop contains a boring-mill with table 13 feet in diameter, one cylinder boring, and one 5-ft. boring mill; one floor boring-machine with iron floor-plate, 10 ft. x 20 ft., 5 planers, ranging from 2 ft.x 7 ft. to 7 ft. x 30 ft.; three shapers; ten lathes, including one 48-in. x 24 ft. bed, and a 7-ft. wheel lathe; a 100-ton hydraulic wheel

press, drill presses, gear cutters, and a complete range of modern tools for all purposes. For heavier work there is a combined slotter and boring-mill with a shifting table of 16 feet traverse. The slotter has a stroke of 4 feet, and the slotting head a movement of 12 feet across and 6 feet vertical. The boring-mill, being attached to the same cross-head as the slotting head, covers a like sectional area. The machine will therefore accommodate a piece of work 12 ft. x 6 ft. x 16 ft., and slot, plane, or bore it at one operation. For facilitating heavy work, the advantages of such a tool are obvious.

The power in the main shop is furnished by a vertical engine with 19-in. cylinder and 24-in. stroke, making 55 revolutions per minute, driving the line shaft at 150 revolutions per minute. The boilers, of tubular pattern, are located in a fire-proof building a short distance from the shop, and are six in number, 60 in. in diameter and 18 ft. long. They also furnish power to thirteen engines of various dimensions used in the foundry, boiler, and wood-working shops.

The machine-shop also contains two 25-ton and three 10-ton jib-cranes. The tool-room is 50 ft. x 50 ft., adjoining the main building, and is provided with stone and emery grinders, lathes, presses, and other tools.

The slopes of the hills flanking Johnstown have been cut through the coal measures, affording the outcrops of the lower five principal seams of coal, surmounted with a valuable bed of carbonate iron ore, the whole capped with the barren measures.

The coal and iron ore-beds can be readily opened by adits driven into the hill-sides, affording ready drainage and easy access, and supplying the works with coal at a minimum cost, and of such quality as is desired in the varied metallurgical operations.

The company own, in fee simple, 51,423 acres of mineral land, and have leased one thousand acres of Connellsville coking land, on which are five hundred bee-hive coke-ovens, which will afford a coke supply for the next thirty years.

It also owns several valuable tracts of land on the Menominee Iron Range in northern Michigan, on which have been opened eight large iron-ore mines, capable of producing 350,000 tons of Bessemer ore annually.

The home mines of the Cambria Iron Company are located in the middle of the great Apalachian coal-field. The measures are nearly level, with sufficient inclination to afford equalizing gradients in mine-hauling, and ready exit to mine waters.

The *Rolling Mill Mine* is situated on the south side of the Conemaugh River, opposite the iron and steel works. It is the main source of supply for these works, delivering from 150,000 to 200,000 tons of coal per year. The seam is $3\frac{3}{4}$ feet thick, and the mining-face is 3 miles broad, with an outspread of coal in advance 5 to 6 miles square. The coal in this bed is specially adapted for heating and puddling iron, and generating steam, from the fact that its sulphur is fixed in plates of selenite, and goes into the ash rather than into the iron. The coal is hauled in trains, by mine locomotives from a central point in the mine, $1\frac{1}{2}$ miles underground, and distributed to all points of the works without breaking bulk. This mine also supplies coal for domestic use to the employees, as well as to many citizens of the towns.

The *Cushon and Lower Gautier Mines* supply the Gautier steel and wire works. The coal is a little more bituminous than the rolling-mill bed. It is $3\frac{3}{4}$ feet thick, of very clean coal without slate partings. These mines produce from 80,000 to 100,000 tons of coal annually.

The *Woodvale Mine* is located on the south bank of the Conemaugh, near Johnstown. It supplies coal to the large woolen and flouring mills at this place.

The *Conemaugh Mine* is situated north of the furnace of that name, supplying its coal for making coke. This coal is similar in quality to that of the Cushon Mine, and makes a good quality of coke.

The *Bennington Slope Mine*, on the eastern slope of the Allegheny mountains, near its summit at Gallitzin, is worked in the second coal bed of the lower measures. It is 3 feet thick and produces about 110,000 tons of coal annually. The main portion of its output is used to supply the 100 bee-hive coke-ovens at this mine. The coke produced is second only to the standard Connellsville coke. This coal is also excellent for smithing purposes, and is shipped to Johnstown, Hollidaysburgh and Springfield.

The *Morrell and Wheeler Slope Mines*, near Connellsville, in the great coke region, supply coal for 500 bee-hive coke-ovens. The coal bed is about 8 feet thick, soft and easily mined. These mines have an annual output of 300,000 tons and furnish coal for the principal supply of coke for the Cambria Iron Company's furnaces. It is the best coke that has yet been made in America.

The yearly output of all the company's coal mines is about 650,000 tons.

Benshoof's Mine, at Johnstown, has been producing 30,000 tons of carbonate iron-ore per year, until recently. The seam is from 18 to 20 inches thick. A small coal-mine attached supplies coal for burning this ore.

The *Frankstown fossil ore-mines* are three miles east of Hollidaysburgh, and have yielded 30,000 tons of ore yearly. The ore is 18 in., of good quality, and yields 45 per cent metallic iron.

It is a peculiar local deposit and has not been found at any other place in a workable condition. It is distinct from the regular and extensive fossil ore-beds in the higher portion of the Clinton Group formation.

The *Springfield mines* consist of four sections of an extensive hematite ore-range. The ore is found, mixed with clay, in large pits in limestone, resting, sometimes, on the Potsdam sandstone.

The ore is washed in a series of Thomas washers, and some of it is jigged in Bradford's jigs, affording an average of 40 to 45 per cent of metallic iron.

The four mines at this place produce from 45,000 to 50,000 tons of excellent Bessemer ore yearly. They are all about 70 miles southeast of Johnstown.

The *Henrietta Mine* is similar in general shape and mode of working to the Springfield mines, but the ore is not so valuable for Bessemer steel, and has therefore been suspended for the present.

The annual product of the "Home mines" ranges from 150,000 to 200,000 tons of ore.

Michigan Mines.—The *Menominee iron ore mines* consist of eight large mines opened on this range along the Menominee River R. R., a branch of the Chicago and Northwestern R. R. The mines occupy points along 8 miles of this iron-ore range and have an aggregate annual capacity of 350,000 tons. This ore is mainly of the best quality for Bessemer iron, and is shipped by rail to Escanaba, thence by lake to Cleveland, and thence by rail to Johnstown.

The mines are in good condition, with plants of modern winding and pumping machinery. The ore deposits are in lenticular masses from 6 to 200 feet thick.

The Cambria Company receives about 150,000 tons of limestone yearly for use at the home furnaces. It owns the large quarries at Birmingham, near Tyrone, from which 76,000 tons were shipped in 1883. It rents the Cresswell quarries at Hollidaysburgh, controls two others in that vicinity, and has a dolomite limestone quarry near Henrietta, in Blair county.

The company purchases manganiferous and other ores, of which an estimate would probably be 40,000 tons annually.

The following table will give the

	Tons.
Average yearly coal output . .	650,000
" " iron-ore output .	450,000
" " limestone " . .	150,000
" " purchases . . .	40,000
Total	1,290,000

The large tracts of coal, iron-ore and limestone lands, owned by the company, have all been carefully selected for specific purposes in the several metallurgical processes in the manufacture of iron and steel rails, and the other varied products of the works, enabling it to control and regulate these supplies so as to insure the utmost economy and to command a wide selection of ores and fuel for the production of the best materials of each kind. They also render the management independent of fluctuations and vicissitudes of the general market, and enable it to sustain a high degree of uniformity in the quality of its productions.

The property is well provided with *railways.* The company owns and operates over 30 miles of standard, and 52 miles of narrow-gauge road, more than 40 miles of which are underground. The transportation of the coal and ores from the mines to the mills and blast-furnaces, and of the pig metal and crude and finished products to the various parts of the works as required, is done by locomotives, of which there are 23, varying from the largest, ordinary type of 37 tons, standard gauge, to the 6-ton narrow-gauge stackless locomotives that are used in the mines. There are in service 360 standard-gauge cars for carrying coal, coke, ore and limestone, and 1000 narrow-gauge cars for transporting ore and coal. The number of standard-gauge cars handled in and out of the works averages 9000 per month.

The products of the establishment are distributed by the Pennsylvania, and the Baltimore and Ohio railroads, the extensive connections controlled by them in every direction being thus reached directly; those of the southwest, including the extensive territory commanded by the navigation of the lower Mississippi, are reached by the slack-water navigation of the Ohio river from Pittsburgh.

An important feature of the organization consists in the extensive collateral industries that it has established and developed.

The *Woodvale Woolen Mill*, located a short distance east of Johnstown, on the Pennsylvania railroad, has twelve sets of cards and a monthly capacity of 50,000 yards of finished cassimeres, the product being chiefly sold in eastern markets. This mill largely employs the labor of the women of the families of operatives in the iron and steel mills.

The *Woodvale Flouring Mills*, situated here, have a daily capacity of 150 barrels. These mills are built of brick, are large and well adapted to their special needs, equipped with modern machinery, and protected from fire by the most recent fire-extinguishing devices. Power is supplied to the flouring mill by an 18-in. x 48-in. engine, and to the woolen mill by a 30-in. x 42-in. vertical engine. Another flouring mill is located at Hollidaysburgh, with a daily capacity of 50 barrels.

The firm of Wood, Morrell and Company, limited, has a large store at Johnstown, divided into seven departments, each of which is entirely distinct and conducted as a separate organization. The departments sell articles of all descriptions and transact an annual business of upwards of 1,000,000 dollars. The firm has stores also at Hollidaysburgh, Bennington, Springfield, Frankstown, Henrietta, Birmingham, and Morrell. It has an abattoir at Johnstown in which 20 to 25 head of heavy western cattle, and 75 to 100 head of hogs, sheep and calves are slaughtered per week. A smaller abattoir is situated at Hollidaysburgh.

Among other industries in which the company has a controlling interest may be mentioned *brickworks* that have a capacity of 25,000 machine-made red bricks per day; *gas-works* sufficiently large to supply not only Johnstown, but its numerous contiguous boroughs; *water-works*, supplying by gravity the mills and town from four main sources of supply. One, with a dam of 6,000,000 capacity, 170 feet head, is located on the Conemaugh River, 5½ miles distant; one, with a dam of 5,500,000 capacity, 165 feet head, on Laurel Creek, four miles distant; one with a dam of 21,000,000 capacity, on St. Clair Creek, 3 miles distant, in the mountains, from which the drinking water used throughout the mills and town is obtained; and one pumping station at Coopersdale, two miles below the works on the Conemaugh River, equipped with two Worthington compound duplex pumps with 21-in. and 36-in. steam cylinders, and 22-in. plunger of 3 ft. stroke, each with a capacity of 5,000,000 gallons per day; also a reserve pump at Woodvale woolen mills of same size. Numerous

pressure pumps distributed throughout the mills and blast-furnaces, three steam fire-engines in the town, and automatic fire-sprinklers in the various shops, constitute a formidable safeguard against loss by fire.

The works are lighted by 95 *electric lights* of the Brush and the Thomson-Houston patterns. The dynamo-electric machines are centrally located and are driven by a Porter-Allen high speed engine of 100 horse-power, supplied with steam from blast-furnace boilers. All parts of the establishment are connected by *telephone*.

The Cambria Iron Company has taken every means to improve the condition of its workmen. The *library* is a large and handsome structure built by the company, endowed by the liberality of its stockholders, and especially designed for this purpose. Besides its collection of 6000 volumes, it contains a fine reading-room and an abundant supply of daily newspapers, periodicals and magazines. A chess-room occupies a part of the building. The upper story is used as a lecture and class room and is in constant use throughout six months of the year. Mechanical and free-hand drawing, mathematics, geology, physical geography, political economy, and chemistry are taught in the evenings by instructors provided by the company without expense to the pupils.

A *Mutual Benefit Association* and *Accident Insurance Company*, established under the supervision of the Administration, is in successful operation. A *surgeon* is employed to attend all employees injured in or about the mines or works, and an ambulance is always in readiness.

The workmen are encouraged to build their own houses; upon application, a lot is assigned by the company, the necessary building materials are furnished, and the price is deducted in small sums from the wages of the applicant until the debt is paid.

The Cambria Iron Company is entirely independent of "*unions*." After the strike of 1874, when the works were stopped for six weeks, a special police force was organized to protect the company's men, and a rule was established that any person belonging to any secret organization or open combination, whose aim was to control the wages, or stop the works, or any part thereof, should be promptly discharged. It is notable in this connection that during the labor riots at Pittsburgh and elsewhere in the summer of 1877, there was no strike among the Cambria's workmen.

At the time of first building the works at Johnstown, the popula-

tion of the town was about 2000. It now contains, with its four adjacent boroughs, more than 22,000 inhabitants, of whom the following numbers are employed in the various departments:

Mines and Coke Yards, Johnstown		375
Blast Furnaces	"	500
Bessemer Steel Works	"	600
Open-hearth "	"	125
Rolling Mills	"	1600
Shops	"	1200
Gautier Steel Depart't	"	1300
Johnstown Manuf. Co.	"	300
Wood, Morrell & Co.	"	200
Blair Iron and Coal Co.		600
Connellsville Coke Works		500
Menominee		800
Springfield		125

Midvale Steel Works.—The works of the Midvale Steel Company (Plate LXXI.) are situated at Nicetown, within the city limits of Philadelphia, and on the line of the Germantown branch of the Philadelphia and Reading Railroad. The erection of the works was begun in 1866 by other than the present management. They were at first planned for the production of crucible steel only, with locomotive-tires as the principal finished product. In 1869–70, a rolling-mill was added to the plant, and a 23-inch train put in for the purpose of rolling the steel for the St. Louis bridge. This undertaking proved very disastrous, financially. The losses thereby incurred, together with former bad management, brought the works practically to a standstill as regards the manufacturing, although its financial credit was maintained.

In the meantime, a small open-hearth furnace had been added to the plant, but no satisfactory products were obtained.

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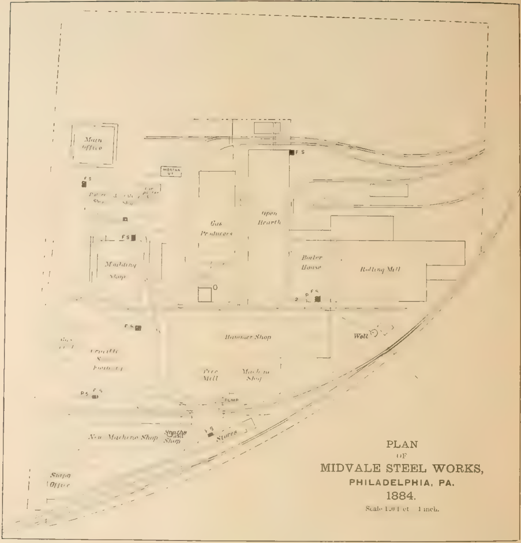
Open Hearth
Gas Producers
Boiler House
Rolling Mill
Hammer Shop
Well
New Machine Shop
Stores
PLAN
OF
MIDVALE STEEL WORKS,
PHILADELPHIA, PA.
1884.

tion of the town was about 2000. It now contains, with its four adjacent boroughs, more than 22,000 inhabitants, of whom the following numbers are employed in the various departments:

Mines and Coke Yards, Johnstown		375
Blast Furnaces	"	500
Bessemer Steel Works	"	600
Open-hearth "	"	125
Rolling Mills	"	1600
Shops	"	1200
Gautier Steel Depart't	"	1300
Johnstown Manuf. Co.	"	300
Wood, Morrell & Co.	"	200
Blair Iron and Coal Co.		600
Connellsville Coke Works		500
Menominee		800
Springfield		125

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hardness and quality could be produced. The laboratory at once found ample employment in determining the quality of and classifying the large amounts of unknown scrap that had been left on the ground by the former management. Great benefit has also been derived from the very large amount of chemical work done in raw material, in products, and in samples of steels of other manufacture, in developing the system now in force, in determining what grades are best suited for given purposes, and in producing with certainty products of a desired composition.

In the present plant, the *melting department* comprises three open-hearth furnaces—one of 7 tons, and two of from 12 to 15 tons capacity; also the old crucible foundry, which contains a number of coal-melting fires and one 30-pot Siemens gas-furnace. The addition of a 25-ton travelling-crane to the open-hearth plant is contemplated, by which the products of two or more furnaces can be brought together and the casting of heavier ingots effected.

The *forge* contains eight steam-hammers, all but one of Wm. Sellers and Co.'s manufacture. The largest has a falling weight of 9 tons, with top pressure steam. Its tup weighs 7 tons. It is considered that an ingot 30 inches square offers the maximum section which this hammer can penetrate. The products of the forge consist of punched and beaked tire-blooms prepared for rolling into tires, general locomotive forgings, car-axles, hammered tool-steel, and miscellaneous forgings, large and small, including those for ordnance purposes.

The *tire-mill* contains one horizontal Galloway mill, on which tires up to 80 inches external diameter can be rolled. The larger portion of the total product of the works is now turned out from this mill.

The *rolling mill* contains a 23-inch and a 12-inch train. The former is notable, in that the material for the two most prominent steel-bridges (St. Louis and Brooklyn) in the country has been rolled on it. On the 12-inch train, general merchant bars are produced, including a considerable amount of gun-barrel steel. The larger portion of gun material used at the Springfield Armory, of late years, has been rolled on this mill.

A *machine-shop* now contains principally tools for turning and boring tires, and turning axles.

The *new machine-shop* is about completed. It is so planned that it can be extended for the reception of heavy lathes and other tools for ordnance work.

The *moulding-shop*, fitted for moulding steel castings, is in constant

use, and an approach to perfection has been attained in the production of solid steel-castings.

While the *oil-tempering plant*, O (Plate LXXI.), for tubes, jackets, and heavier forgings, is an experiment, some excellent results have already been obtained, and hoops, projectiles, and gun-forgings have, for some time, been successfully treated.

Numerous hydrants H, pumps P, and fire-stations, FS, provide an efficient defence against fire.

The first attempts in the production of material for ordnance was made in 1877, when a number of short tubes were manufactured for the Bureau of Naval Ordnance, to be used in lining 100-pounder and 60-pounder Parrott guns. The quality of these tubes was thoroughly tested before acceptance, by breaking transverse and longitudinal test-bars cut from them. The results of these tests were in general very satisfactory. A long, soft tube, and a harder jacket were made in 1878 for the conversion of a 10-inch Parrott into a 9-inch rifle.

A number of howitzer-forgings have also been furnished to the Navy from time to time. In the spring of 1881, the steel parts of the Lyman-Haskell 6-inch multicharge gun were fabricated. These consisted of a forged tube and breech-extension piece, and unforged solid castings for the powder pockets. The tube was 23 feet long, of 10½ to 11½ inches diameter, and weighed nearly 4 tons.

In the spring of 1882, the manufacture of various parts of two experimental 6-inch all-steel breech-loading rifled guns was undertaken for the Navy. These parts were furnished in the rough, and the guns were fabricated at the Washington Navy Yard. One of these guns was to be hooped, and the other wire-wound. The hooped gun has recently been completed, is now being tested at the proving-ground at Annapolis, and is the first all steel 6-inch breech-loading rifle manufactured in the United States, entirely of American material.

There are now in process of manufacture, the parts of a number of 5 and 6-inch all-steel hooped guns intended for the armament of the new cruisers.

An experimental steel tube has been recently furnished to the Army Ordnance Department, for the conversion of a 10-inch Rodman gun into an 8-inch rifle; and a number of hoops, both rolled and hammered, are now being fabricated for hooping a 12-inch cast-iron mortar, and an 8-inch all-steel, built-up breech-loading rifle.

The results of the careful mechanical tests, made in these various

parts, are of such a satisfactory nature as to leave no reasonable doubt that material, well suited to the construction of high-power steel guns, can now be furnished at these works with certainty, up to the capacity of the present plant.

The management has stated that what will be done in the near future, in the direction of adding such appliances as will render possible the manufacture of parts of guns of larger caliber, will largely depend upon what steps are taken by the Government to insure a sufficient amount of work to justify the large outlay necessary.*

Springfield Iron Works.—This establishment is situated at Springfield, Illinois, 95 miles from St. Louis, and 180 from Chicago. It is in direct rail communication with all parts of the United States, eight important railways centering here. The iron-ore markets of the above-named cities are therefore in convenient connection, and the shaft of an extensive bituminous coal-field is within 500 feet of the works. The supply of coal and ore is thus cheap and certain.

The works cover a level tract of 45 acres, and in July, 1882, comprised the following plant:

The *puddle-mill*, put in operation in 1872, contains: six double puddling furnaces; one train of two stands of 18-inch rolls, squeezer attached, driven by a 28x60-inch horizontal Corliss engine; also a 2-ton hammer for shingling puddled balls.

The *rail-mill*, put in operation in 1872, contains: six Siemens gas-heating furnaces, and twenty gas-producers; one 23-inch train of rolls with three stands, driven by a vertical engine 40-inch diameter, 36-inch stroke; also supplied with Maharg's charger, a steam pull-out, and Gustin's hot-curving apparatus; product, steel and iron rails; annual capacity, 60,000 net tons.

The *bar-mill*, put in operation in 1878, contains: four Siemens gas-heating furnaces; one 16-inch train of rolls and one 12-inch train, driven by a vertical 29x39-inch Corliss engine; product, fish plates and bar iron; annual capacity, 20,000 net tons.

The *steel-melting house* contains two 15-gross-ton Siemens open-hearth furnaces with Pernot hearth, built in 1879, from which the first steel ingot was made in 1880; one Pernot furnace and two cupolas for pre-melting for the steel-making furnaces, and for dephosphorizing the metal by the Krupp process (see page 771); twelve gas-producers.

The *blooming-mill* contains: a stand of 30½-inch rolls, built in 1879,

* See Letter, page 567.

rolls all fixed; two Siemens heating-furnaces, with power fixtures for charging and drawing; shears for cutting blooms; blooming-train run by a 32 x 60-inch Corliss engine; steam supplied by six tubular steel boilers; sixteen gas-producers supply the furnaces in the bar and blooming mills.

Of the open-hearth plants, Mr. A. L. Holley and Mr. Lenox Smith, in an article published in the London *Engineering*, May, 1880, wrote:

The Springfield Iron Co. was the first in the United States to adopt the Krupp system of washing phosphorus out of pig-iron, and the second to introduce the Pernot revolving and movable hearth,—two systems essential to the cheap manufacture of open-hearth steel.

The furnaces stand high enough to give a roomy and well-ventilated floor all around them on the general level, and also a conveniently shallow casting-pit. The upper part of the regenerators, and also the reversing-valves, stand accessibly above ground.

The charging-floor and appurtenances are on the opposite side from the casting department. A movable charging-platform on the tapping side, as at St. Chamond, France, is very inconvenient.

Casting is done by means of an ingot crane of large radius, rather than by the less convenient and less easily moved ingot-car. There is a platform in front of the furnace for dressing the tap-hole. The arrangement is such that the ladle may be moved over the ingot-moulds; or, steel may be running into the ladle and at the same time out of the ladle into a group of moulds.

The furnaces stand in a single line, giving a concentrated stock-yard and a producer-house (reached by the same elevated railway system) on one side, and a cool casting-house and an ample ingot-yard at the other.

The chief advantage of the revolving-hearth is mechanical agitation, which facilitates the chemical reactions. The important benefit of the removable hearth is convenience and economy of repairs. The ordinary repairs do not, as in the case of the stationary hearth, interfere with the continuous production of steel.

The sustaining and revolving gear of the hearth are not materially changed from Mr. Pernot's designs, page 692, except that a water-cooled center pintal has been provided to resist the lateral thrust of the hearth.

The arrangement of the pig-melting and washing apparatus is intended to promote the least handling of materials, and also good ventilation. This matter of ventilation, so often alluded to, is one upon which great stress is laid. The concentrated heat in the working places of many establishments is so trying that men cannot do a normal day's work, and cannot continue the work they do year after year. It is not only economical, but humane, to arrange a plant so that men can comfortably perform the best work there is in them.

The cupola furnaces are set 12 feet from the open-hearth house, and their slag discharge is directed away from other operations. One hydraulic hoist raises materials with equal convenience to the charging-floors of the cupola, and to the washing and steel furnaces. The flow of fluid metal from the cupolas to the washing-furnace, thence to the ladle, and thence to the steel-fur-

naces, is short and direct. There is no lateral transference of melted metal in ladles; the washed-metal ladle stands permanently on a lift, and is once raised vertically. The time and labor attendant upon swinging, turning, and drawing about heavy ladles on cranes, turn-tables, and cars are expensive and the chances of accident are great.

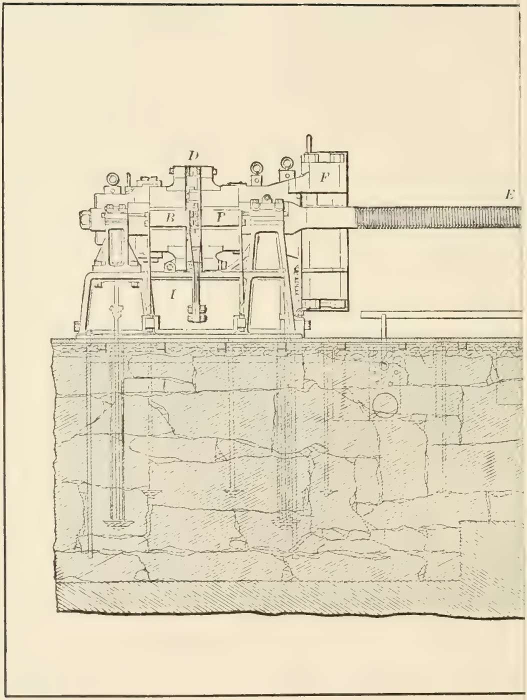
At the present time three Pernot open-hearth furnaces are so arranged that an ingot of 40 tons can be readily cast, and a large roll for steel plates of great thickness and up to 110 inches wide, has recently been completed; but no provision for forging masses equal to its casting capacity has yet been made.

The management has indicated its willingness to undertake the development of an adequate plant for providing steel for modern guns if a "fairly remunerative business" is assured. *

A large number of steel manufactories are supplied with steam-hammers of from 3 to 4 tons tup: the following table contains a list of the principal steam-hammers in the United States, having a tup heavier than 4 tons:

Name of Company.	Where Situated.	Weight of Tup, Tons.
Cincinnati Rolling Mill	Cincinnati, Ohio	5
Old Fort Iron Mills	Brownsville, Pa	5
Edgar Thomson Steel Works	Bessemer, Pa	6
Pennsylvania Steel	Steelton, Pa	6
Midvale Steel	Nicetown, Philadelphia, Pa	7
Standard Steel Works	Logan, Pa	7
Navy Yard	Washington, D. C	7½
Standard Steel Works	Logan, Pa	10
Navy Yard	Boston, Mass	11
Nashua Iron and Steel	Nashua, N. H	12
Pennsylvania Steel	Steelton, Pa	12
Bridgewater Steel Works	Bridgewater, Mass	17
Park, Brothers & Co	Pittsburg, Pa	17

* See Letter, page 568.


D
F
E
B
P
I

Emery Testing Machine.—This machine is the property of the United States Government and was manufactured for the Board of Engineers created to test iron, steel, and other structural materials. Among various provisions, the Chief of Ordnance, War Department, is required to "give attention to such programme of tests as may be submitted by the American Society of Civil Engineers, and the record of such tests shall be furnished said society, to be by them published at their own expense."

The machine, composed of parts manufactured at various foundries and shops, was erected in 1879 at the Watertown Arsenal, Mass. The following extract is taken from a description prepared by Captain J. Pitman, U. S. A., and published with 12 plates in the Report of the Chief of Ordnance, War Department, for 1883:

The United States Government testing machine is the invention of Mr. A. H. Emery, of New York.

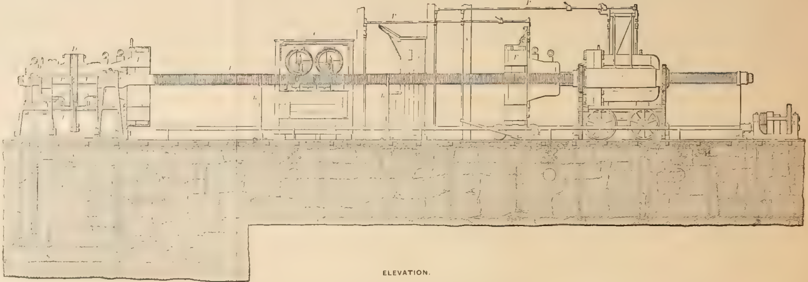
It is a horizontal hydraulic machine, has a capacity of 800,000 pounds for strains of tension and compression, and can test specimens of any length up to 30 feet, and of width not exceeding 30 inches. By a slight modification it is adapted for compression tests of 31 feet 2 inches in length, and for tensile tests of eye-bars 37 feet 3 inches from center to center of eyes.

The principal parts (Plate LXXII.) are the platforms of a hydraulic scale at one end and a straining press at the other, connected by two 8½-inch wrought-iron screws E, 48 feet long, supported horizontally 47 inches above the floor and 50 inches apart. Four bronze nuts working upon these screws are in contact with either end of the press, and are connected by gearing with a splined shaft below, extending between tracks parallel to the screws. This shaft is actuated by a live head at one end worked by steam-power.

The *straining press* A has a cylinder 20 inches diameter and 24 inches stroke. It is mounted on a truck which runs on the tracks between the screws, and is brought nearer to or farther from the scale platforms, to accommodate different lengths of specimens, by operating the live head which revolves the shaft, which in turn works the bronze nuts.

The *scale platforms* B are vertical, and capable of a slight longitudinal movement, being suspended and restrained by vertical and horizontal springs, which also serve to give the platforms an initial pressure against each other. Between the platforms are placed, symmetrical with the line of traction, four sealed columns of liquid D, called *supports*, which, when the platforms are pulled or pressed together by the movement of the piston of the straining press attached to the other end of the specimen being tested, receive the strain and transmit it through one-tenth inch copper tubes to four similar but smaller *supports* in the scale case. These act by their expansion on levers, raising a vertical rod which presses against the *beam of the scale*. The weights required to balance this beam indicate the strain on the specimen in the machine.

PLATE LXXII.



ELEVATION.

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The hydraulic power is supplied by a *steam-pump* working into an *accumulator*, instead of into the straining-press cylinder direct. This avoids the pulsations caused by pumping, and facilitates the manipulation of the machine. The *accumulator* has a vertical 10-inch cylinder and ram; the latter of which in turn contains a 5½-inch ram. Either ram may be used to lift one, two, or three heavy masses of masonry, which are keyed, when desired, to a vertical wooden post resting on the inner and smaller ram. This arrangement allows of a variation of pressure from 380 to 3400 pounds per square inch, or on one face of the piston of the straining-press cylinder—having the largest available area—a pressure varying from 119,400 to 1,068,000 pounds, and on the other face a pressure varying from 89,500 to 801,100 pounds. The larger limit occurs in the case of compression, and the smaller in the case of tension tests. Either ram and one or more of the weights can be used, depending upon the strength of the specimen.

The liquid (sperm oil) being pumped from a tank into the accumulator, the pressure obtained by means of the weights is transmitted to either end of the press cylinder by *jointed pipes* P, controlled by valves in the scale case, the handles of which are convenient to the operator's hands.

Attached to the piston rod of the straining press, and mounted on a truck so that it can move with the press, is the *movable holder*. A like but *stationary holder* is attached to the scale platform, but is balanced on vertical rods. These holders, consisting each of three heavy castings, are furnished with hydraulic presses, and have for their function to grasp between their jaws each an end of the specimen to be tested.

In addition to the scale beam, which weighs the load received at one end of the machine, *pressure gauges* C indicate the strain in the cylinder. Like gauges also indicate the pressure of the jaws upon the specimen.

Underlying the whole machine is a solid masonry *foundation*, upon which it rests. The tracks are bolted to this foundation, and are laid in sulphur bearings. At the platform end there is a thick cast *bed plate*, on the same level as the tracks, likewise laid in sulphur, and firmly fastened to the foundation. Upon this bed plate rests a large cast-iron box-like *stanchion*, upon which are suspended by springs and rods the platforms themselves and their holder. It also has four *pillow blocks*, which support one end of the great screws; their other ends being supported by spring struts. There are also intermediate *rests* R, for the screws, and *bearings* for the splined shaft, which are so pivoted and balanced as to turn down out of the way of the movement of the press and its holder.

All the parts above the *bed plate* are stationary when in use, as regards their relative positions only, the whole system being allowed a slight longitudinal motion, which is gradually checked by buffer springs. This prevents injury from the shock of reaction, resulting from the sudden breaking of the specimen.

It is claimed for the Emery machine that it has "over any other, an advantage as regards capacity, delicacy, accuracy, convenience of application, and manipulation, and impunity from injury due to the shocks of recoil."

Another very interesting description was published in "Mechanics," Vol. IV, Nos. 96 and 97.

Mr. Arthur V. Abbott, in his article on "Testing Machines," written for "Van Nostrand's Engineering Magazine" (Nos. 183, 184, 185), states that he is of opinion that the results of this machine are liable to criticism because "the only method of insuring the coincidents of the axis of stress and the axis of the specimen is by carefully measuring and centering the piece with reference to the axis of the machine, and in one built on so large a scale as that at the Watertown Arsenal, much more time may be consumed in this process of centering than in any other part of the test." He considers, however, that its great merit lies in its sensibility.

PRESENT CONDITION OF THE ARTILLERY OF THE UNITED STATES.

> "To recite under this heading the present armament of the country is unnecessary. Before the introduction of rifled cannon and the use of steel as the material for their construction, the United States boasted of her Dahlgren and Rodman cast-iron guns, which were the models for imitation and the standards for comparison of all nations.
>
> While the rest of the world has advanced with the progress of the age, the artillery of the United States has made no step forwards. Its present condition of inferiority is only the natural result of such want of action." *

Under the small appropriations, made by Congress at its last session, some advance has been made in experiment, and the following contracts were made by the War Department:

1. For converting fifty 10-inch Rodman smooth-bore guns into 8-inch rifles, by lining with a coiled wrought-iron tube.
2. For making two 12-inch cast-iron breech-loading rifles, one of which is to be lined as far as the trunnions with a steel tube wrapped with wire.
3. For making one 12-inch cast-iron mortar, banded with steel hoops.
4. For making one 10-inch cast-iron breech-loading rifle, wrapped with steel wire, and one 12-inch cast-iron breech-loading rifle, tubed, and banded with steel hoops.
5. For the tubes, hoops, &c., for one 8 and one 10-inch steel rifle.

In the Navy Department, the Chief of Ordnance, though limited by insufficient appropriations, has been enabled by the purchase of

* Gun Foundry Board Report.

material abroad and the assistance of the Midvale Steel Company, to advance the fabrication, at the machine-shops of the Washington Navy Yard, of seventeen all-steel guns of from 5-inch to 10-inch caliber, from designs that promise excellent results.

Plates LXXIII., LXXIV., represent the Bureau's designs for the construction of 6-inch and 8-inch breech-loading hooped guns. They are of the type generally accepted by the leading artillerists, the longitudinal strength being provided by the long jacket, while the tangential strength is increased by a judicious arrangement of hoops.

The 6-inch hooped B. L. R. (Plate LXXIII.) is composed of a chambered tube 15 feet 4 inches long, a jacket J, 6 feet 1.4 inches long, and a series of hoops A, B, C, D, E, F, G. Its weight will be 11,000 pounds, and the center of gravity at the center of trunnion.

The locking edges of the jacket and hoops are so finished that the strain will be equally distributed at every point in a direction perpendicular to the tangent of that point, instead of being concentrated at the weakest *angular* spot. The trunnion-hoop is screwed into position.

The 8-inch hooped B. L. R. (Plate LXXIV.) will weigh 27,600 pounds, and is of similar construction, with a chambered tube of 30 calibers, and a jacket about two-fifths its length. An interrupted screw will close the breech, and in all guns will engage in the jacket.

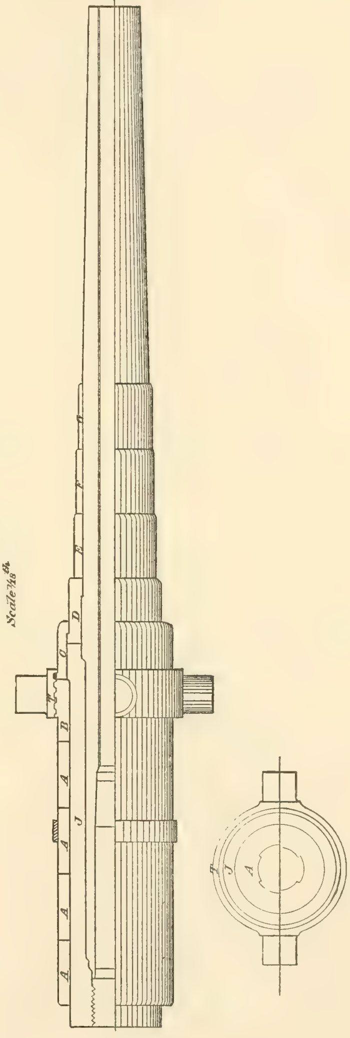
Excellent ballistic results have been obtained at the naval experimental battery, with a 6-inch B. L. R. of similar construction recently fabricated at the Washington Navy Yard.

Wire Construction.—The state of wire-construction in the United States continues to be experimental. Since the bursting of the Woodbridge 10-inch M. L. wire rifle, October 18, 1881, Mr. Woodbridge has departed from the principal feature of his system—winding wire in successive layers upon a steel tube—and now proposes to introduce longitudinal bars, surrounding part of the tube with a broken jacket instead of the well-forged solid jacket so generally accepted.

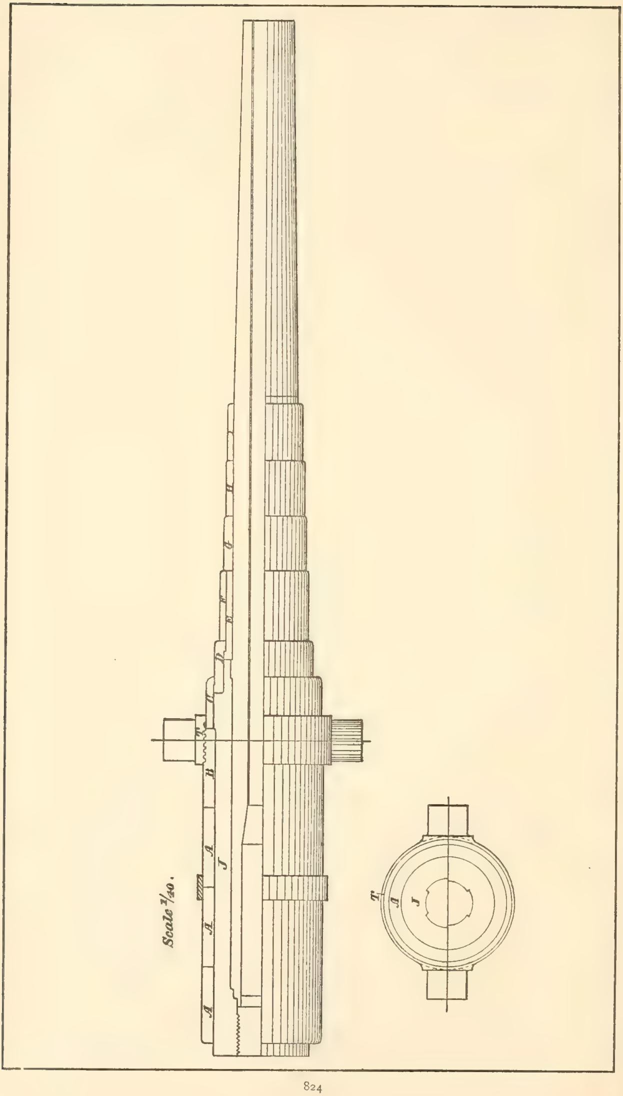
In a pamphlet relating to gun construction on the plan patented by him, Mr. Woodbridge has given the following as the principal features of the system :

The material of which the gun is principally composed is steel wire, drawn square, with the corners slightly truncated.

This is wound upon a steel tube, in successive layers. A sufficient number of wires are wound at once to form, when placed side by side, a band about equal in width to the diameter of the bore of the gun, which gives them the



6-INCH HOOPED B. L. R.—BUREAU OF ORDNANCE, NAVY DEPARTMENT.



8-INCH HOOPED B. L. R.—BUREAU OF ORDNANCE, NAVY DEPARTMENT.

proper obliquity. The tube is closely covered in this way, from end to end, and with layer after layer, until the mass has reached the full size of the gun.

The whole is then inclosed in an air-tight case of boiler-iron, and, thus protected from oxidation, is heated to the melting-point of bronze, when liquid bronze is supplied in such a way as to interpenetrate the mass and unite it when cooled, in one solid piece, to be afterward turned and finished to the proper form and dimensions.

The steel tube on which the wire is wound should be at least thick enough to permit its being re-bored to the proper caliber and rifled, without cutting through it (as it would be undesirable that the surface of the bore should present two metals), some allowance being also made for a possible slight swagging or warping in the process of construction. It may sometimes be desirable to employ a thicker tube—the only objection in any instance being the substitution of the inferior metal of the tube for the stronger material surrounding it. Its length must exceed the finished length of the gun. Each end is provided with a flange, screwed on—the flanges being serviceable for fastening the ends of the wires, and for security in handling after winding. It should be closed at the breech end.

For the purpose of winding, the tube is rotated in a lathe or winding-machine, the wires being drawn between friction-plates which are carried, as the winding advances, with a regulated motion, in a line parallel with the tube.

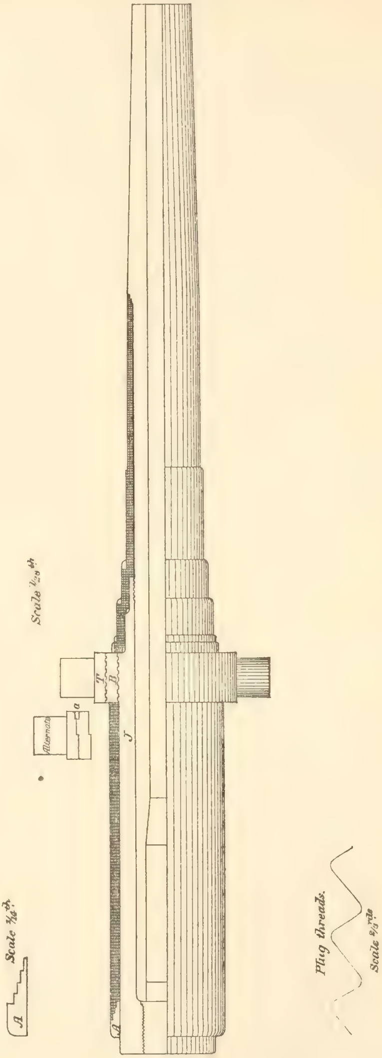
In heating for the brazing process, the closed end of the tube (or breech end of the gun) is placed downward.

The trunnions of the gun may consist of bronze employed in the process of soldering, spaces for receiving the metal being provided within the case protecting the wire from oxidation.

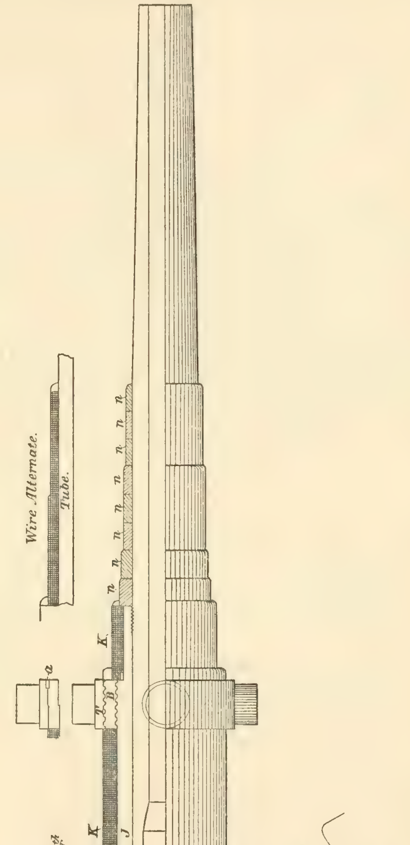
The most practical application of the wire question appears in the designs for 6-inch and 8-inch wire-wound B. L. rifles, prepared by the Bureau of Ordnance, Navy Department. In them the weight of the gun is decreased and the tangential strength increased by substituting wire for the hoops.

The 6-inch wire-wound B. L. R. (Plate LXXV.) consists of a chambered tube 15 feet 4 inches in length, a jacket J, 7 feet 3 inches long, and the wire wrappings. The trunnion-hoop will be in two parts and screwed as indicated in the plate. In the alternate, the locking-ring *a* may or may not be used. The weight of the gun will be 10,500 pounds, including the breech-plug, and the center of gravity will be at the center of trunnions.

In the 8-inch wire-wound B. L. R. (Plate LXXVI.) the chambered tube will be 20 feet 5 inches long, and the jacket J, 9 feet. The weight of the gun, 26,500 pounds, is more than 1000 pounds less than that of the hooped-gun of same caliber. The construction and fitting of the trunnion hoop are similar to those in the 6-inch wire-wound B. L. R.,



6-INCH W. W. B. L. R.—BUREAU OF ORDNANCE, NAVY DEPARTMENT.



8-INCH W. W. B. L. R.—BUREAU OF ORDNANCE, NAVY DEPARTMENT.

and, as in that gun, the locking-ring *a* may or may not be used. Either the hoops *n*, *n*, or the wire alternate may be employed.

As in the hooped guns the interrupted screw breech fermeture will engage in the jacket.

Mr. Woodbridge has been superintending the construction of a wire-winding machine, and in common with others who have been developing the system, has met many troublesome questions. Some of the difficulties have been overcome by the Inspector of Ordnance and his assistants at the Washington Navy Yard, and, from successful experiments with it, it is believed that a satisfactory machine has been obtained; but, quoting the words of Sir William Armstrong in reference to the system of wire construction: "Of the theoretical advantages of this system there can be no doubt, but the difficulties only begin when we endeavor to put the theory into practice, and no solution of the problem of how to do it can be accepted without the production and trial of an actual gun."

VII.

PLANT FOR THE MANUFACTURE OF GUNS.

" From information gained in its investigations and from consultation with the managers of those large establishments abroad where gun tools are made, the Board submits the following estimates :

As it will recommend that "for the manufacture of heavy ordnance adapted to modern warfare," the steel should be produced by private companies and the guns fabricated in Government shops, these estimates will be made under three heads, viz.:

I. Machines and tools for steel plant.
II. Machines and tools for gun factory.
III. Buildings.

I. Machines and Tools for Steel Plant.

On the matter of plant for casting and forging, the Board obtained information chiefly from Sir Joseph Whitworth & Co., of Manchester, and from Messrs. Tannett, Walker & Co., of Leeds, England.

The following is an approximate cost of plant for casting and forging ingots up to 100 tons, submitted by Tannett, Walker & Co.:

Sixteen groups (4 each) gas producers.

Ten 12-ton Siemens furnaces.

Two large re-heating furnaces.

Five 24-ton hydraulic center-casting cranes.

Six 5-ton ingot cranes.

Two 170-ton and two 30-ton power travelling cranes, 50 feet span, with engines.

Two 24-feet by 19-feet hydraulic accumulators.

Two pairs pumping engines ; either 18 inches by 24 inches (single), or 15 inches by 28 inches by 24 inches (compound).

One overhead tank.

Pipes for above hydraulic cranes.

One 3000-ton hydraulic press.

One pair pumping engines for working press.

T otal cost, exclusive of buildings, about $300,000.

This estimate does not include tools for rough boring or turning, nor appliances for tempering.

The additional cost of these tools and appliances should be added as forming part of the expenses properly belonging to the foundry. As will appear hereafter, the cost of a complete plant for rough boring and turning, including all guns up to 100 tons, will be about $210,000 ; the tempering pit, furnaces, &c., will cost about $50,000 ; which, exclusive of buildings, would, upon the estimate of Tannett, Walker & Co., make the total cost of a plant capable of casting, forging, rough-boring, rough-turning and tempering the parts of guns up to 100 tons, about $560,000.

The following is an estimate from another source, for a 100-ton ingot steel plant, confined exclusively to the process of casting :

Eight 15-ton Siemens furnaces, with platform and producers complete.

Two ordinary travellers for ingot-pit.

Eight 15-ton ladles.

Railway metal and laying.

Hydraulic cranes.

Cost, exclusive of buildings, about $215,000.

The following is an approximate price of a plant for casting and forging 72-ton ingots :

Ten groups (4 each) gas-producers.

Six 12-ton Siemens furnaces.

Two large re-heating furnaces.

Three 24-ton hydraulic center-casting cranes.

Pipes for hydraulic cranes.

Four 5-ton ingot cranes.

Two 100-ton and two 30-ton power travelling-cranes, 50 feet span, with engines.

Two 18-feet by 19-feet hydraulic accumulators.

Two pairs pumping engines, either 18 inches by 24 inches (single), or 15 inches by 28 inches by 24 inches (compound).

One overhead tank.

One 3000-ton hydraulic press.

One pair pumping engines for working press.

Cost, exclusive of buildings, about $2c5,000.

The following is an estimate submitted by Sir Joseph Whitworth for a plant for casting 60-ton ingots :

Three 20-ton melting furnaces, including all steel and iron work, all silica and fire-bricks, valves, levers, stages, ladles, apparatus for making clay used in the moulds and ladles, the iron work and all fire-bricks for gas-producers, a competent man to superintend erection, but exclusive of all common bricks, brick-setting, excavating, &c., $70,000.

This plant, if supplied with a sufficient number of re-heating furnaces and kept in full work, would be capable of turning out 150 to 200 tons of large gun material per week.

The following are estimates submitted by Sir Joseph Whitworth for forging presses:

A 34-inch hydraulic forging press, complete with its engines, pumps, boilers, two hydraulic travelling cranes, two re-heating furnaces with hydraulic apparatus for raising the doors. An assortment of steel chucks, mandrels, draw-bars, porter-bars, swage and other blocks for enlarging and reducing hoops, &c., apparatus for withdrawing mandrels, &c., $200,000.

A 24-inch hydraulic forging press, complete in all details, as in the case of the large one already cited, will cost about $140,000.

The forging press, though not a new idea, has been but little used; in fact, to this time, it has been adopted in but one large establishment in the world; consequently its manufacture is costly. Its general adoption is now a matter of certainty, and its cost will no doubt be reduced; hence, it is probable that a 36-inch forging press with cranes, engines, pumps, accumulators, &c., exclusive of buildings, may be obtained for $150,000.

If the system of liquid compression should be adopted, the additional cost of a hydraulic casting press, complete, including steel mould boxes, overhead hydraulic travelling cranes to lift 100 tons, including columns and girders, and complete in every respect, except masonry and brick-work, would be $175,000.

The following is an estimate of the cost of tools for rough boring and turning the parts of guns for all calibers up to 16 inches:

One rough-turning lathe for tubes and jackets up to 12-inch caliber.
Three rough-boring lathes for same.
One rough-turning lathe for tubes and jackets up to 16-inch caliber.
Two rough-boring lathes for same.
One 100-ton power travelling crane.
One 20-ton power travelling crane.

Tools for the above, including :

Assorted tools for rough-turning lathes.

Forged cast-steel boring bars with head and steel cutters for boring tubes out of the solid.

Forged cast-steel bars for boring jackets.

Sets of tools for each of the hoop and trunnion lathes, and for the slotting machines.

The total cost will be about $210,000.

If a complete set of trepanning tools were to be furnished for the work of rough-boring, the additional cost will be about $50,000. The first cost of these tools is very great, as they are made from very large ingots of cast-steel, oil tempered, which have to be bored and turned almost entirely away.

The above estimates respond to the call of the Act of Congress so far as relates to cost of a steel plant for the manufacture of the heaviest guns, and will answer some of the inquiries of, and serve as a guide for those of our steel manufacturers who shall undertake to supply the Government with the required material for modern artillery.

As the greater includes the less, it may be taken for granted that no plant for smaller work can equal the above estimate. The scale of diminution in proportion to the weight of metal and capacity of cranes, presses, &c., may be approximated, and the following list of weight of forgings required for different calibers in the English service will assist the calculation :

Particulars of Forgings for English Gun Tubes.

Weight and caliber of gun.	Weight of ingot cast.	Weight of forging for tube.	Model.
110 tons	About 100 tons	70 tons	New.
100 tons, 17 inches	Breech part, 27 tons Muzzle part, 15 tons	21 tons, 2 cwt 12 tons, 11½ cwt	Old.
80 tons, 16 inches	21 tons	17 tons, 7 cwt	Old.
63 tons, 13.5 inches	35 tons	27 tons, 17 cwt	New.
43 tons, 12 inches	27 tons	21 tons	New.
26 tons, 10.2 inches	14 tons	11 tons, 10 cwt	New.
18 tons, 9.2 inches	12½ tons	10 tons, 5 cwt	New.
11½ tons, 8 inches	10½ tons	8 tons	New.
80 cwt., 6 inches	4½ tons	3 tons, 12¼ cwt	
38 cwt., 50-pounder	2½ tons	1 ton, 18¼ cwt	
22 cwt., 4-pounder	1½ tons	1 ton, 2½ cwt	

The forging for the 100-ton gun cited above is that which was supplied for the Armstrong gun furnished the Italian

Government, the tube for which was made in two parts. That for the 110-ton gun now to be made for the English Government will be in one forging.

If the cost per ton be fixed for the smaller guns, and an increasing ratio be established per ton as the caliber increases, the approximate cost of the forgings for guns of like pattern can be determined.

From an inspection of the table given above, it will be seen that it is within the resources of many of our own steel works to supply castings for a large number of the different calibers. These works, however, are deficient in forging apparatus.

In the above estimates the cost of a steam-hammer is not given, as the Board unanimously approves the adoption of the press; but it will be pertinent to add that, in order to produce a given amount of work, the hammer is the more expensive tool.

II.—Machines and Tools for Gun Factory.

On the matter of plant for gun factory the Board obtained information from the principal gun factories of England, France, and Russia, where machines and tools are in operation, and from the largest establishments where such tools are made, but chiefly from Messrs. Greenwood & Batley, of Leeds, Mr. Hulze & Co., of Manchester, and Messrs. Varrell, Elwell & Middleton, of Paris.

In considering this part of the subject it was decided that there were three classes into which guns could be advantageously divided in reference to tools suitable for their fabrication, viz.:

1. Guns of 6-inch and all below that caliber.
2. Guns from 6-inch to 12-inch caliber.
3. Guns of caliber greater than 12 inches.

It was necessary to adopt a tool as a unit on which to base the calculation that should determine the number of tools required under the above classes. The rifling machine was the unit adopted. The object was to so proportion the numbers of each tool as to keep the rifling machine constantly employed.

In the solution of this problem the Board has had the advantage of the able assistance of the firm of Greenwood &

Batley, of Leeds, England, whose tools were seen in all the large gun factories visited in Europe." *

Albion Works, Leeds.—The firm of Greenwood & Batley was established in the year 1856, by the late Mr. Thomas Greenwood in conjunction with Mr. John Batley, at the Albion Foundry, East street, for the manufacture of general and engineering tools, flax machinery, &c.

The great changes made in the national armaments during and immediately after the Crimean War, created a new branch of industry in the machine trade, namely, the manufacture of special tools for the production of this improved war material. During the war, Mr. Greenwood, when in partnership with the late Sir Peter Fairbairn, had devoted much attention to the designing and supply of this class of special tools for the British Government manufacturing establishments at Woolwich and Enfield, as it was during that period that these establishments grew rapidly from the very small and insignificant workshops they had hitherto been, to the most important military arsenals in the world. It was thus during the earlier years of the firm's existence that they were very extensively employed in making machinery for the British Government, and later for the various arsenals since established by colonial and foreign governments.

In 1859, finding the East street premises too small for their business, they purchased the site of the present works in Armley Road, and commenced building the Albion Works; it was not, however, until some twenty years later that they were enabled to remove the whole plant and finally close the original establishment.

The Albion Works stand upon some ten acres of land, fronting on Armley Road, and having a wharfage behind on the Leeds and Liverpool Canal. They consist of a principal iron foundry 48 ft. x 146 ft., and a smaller foundry 49 ft. x 66 ft., with cupolas and steam cranes capable of turning out castings of fifteen tons weight, and producing some fifty or sixty tons of castings per week, the great bulk of which being necessarily of a light and intricate nature. Adjoining the foundry is a pattern store of three stories, 48 ft. x 112 ft. The principal machine and erecting shops are built in the form of a T, the longer portion being 72 ft. x 464 ft., and the shorter 76 ft. x 168 ft., both having two stories. The power is supplied by a couple of horizontal condensing engines of about one hundred horse power each, and the

* Gun Foundry Board Report.

shops are well provided with travelling and other cranes. There is a two-storied machine shop fronting Armley Road, 22 ft. x 128 ft., and in the center of the quadrangle is another two-storied building, 68 ft. x 68 ft., the lower floor being used as a machine shop, and the upper one as a patternmaker's shop and drawing office. There are also smithshops containing some thirty fires, well supplied with steam-hammers and other forging machinery. In the lower yard is a range of buildings, 35 ft. x 332 ft., used as warehouses, carpenters' shop, &c. A small forge 100 ft. x 30 ft. and brass and malleable iron foundry 36 ft. x 30 ft. are also situated in this yard. The total shop area is 6,590,090 square feet, and from 1500 to 1600 workmen can be employed.

The various classes of machinery produced by the firm are, engineers' machine-tools of general description, and wood-working machinery, but the greater part of the establishment is occupied in the production of machinery for special purposes. Stamping and forging machinery of all descriptions, including machines for making bolts, rivets, nuts and spikes, machinery to finish bolts, nuts and screws, notably automatic machines for making screws both for wood and metal. Band and circular saws for cutting iron and steel, machinery for testing the strength of material, milling machines for all varieties of work. One department is devoted to the manufacture of printing machinery, whilst another is occupied in producing sewing-machines for the manufacture of boots, belting, harness, &c., and other machines used for making boots, clothing, &c.

At present, a considerable quantity of dynamo machines for electric lighting are being manufactured, together with a large variety of special plant for the production of these machines.

Among the special machinery made for producing arms and military stores are comprised machinery for the manufacture of ordnance of all descriptions, from a fuze to a 100-ton gun.

Among the principal plants of machinery made at these works are, the various plants supplied, both complete and in part, to Her Majesty's arsenal at Woolwich, the Royal Small Arms Factory at Enfield, and the various arsenals in the Indian Empire. A complete plant for making heavy ordnance on the Armstrong and Woolwich plan was supplied some years ago to the Imperial Chinese Government, whilst a similar plant for breech-loading steel field artillery was recently supplied to the Russian Government. To this latter government was also supplied a few years ago a complete plant of machinery

to produce three hundred rifles and bayonets per day; this production has since been doubled by a further lot of machinery sent out from these works. The firm is at present engaged upon a similar plant for the Italian Government to produce 200 rifles and bayonets daily.

The large testing-machine patented and used by Mr. Kirkaldy was made here some years ago; it can exert a strain of 400 tons on all varieties of tests. A duplicate of this machine was lately delivered to the Belgian Government, and many others of different sizes have been supplied to British and foreign dockyards and arsenals and to large private iron works and universities.

> "The members of the firm have spent much time and incurred much expense in providing plans and estimates and have communicated most valuable confidential information. The following estimates, stated in a general way, are the results, and the Board is confident of the essential accuracy.
>
> (1.) COST OF GUN FACTORY PLANT UP TO 6-INCH CALIBER.
>
> This plant does not include rough boring and turning lathes for tubes, jackets, and hoops; these parts are supposed to be supplied ready for finishing. It includes:
>
> Two finish-turning lathes.
> Three finish-boring lathes.
> One lathe to chamber, cut breech-screws, &c.
> One rifling machine.
> One milling and drilling machine.
> One 10-ton power travelling crane.
> Tools for above, including—
> A set of turning tools for each finish-turning lathe.
> One boring bar with head and cast-steel tools for boring lathes.
> One chambering bar with cutting tools.
> One steel bar and cutting tools for screw-cutting and shaping out spaces.
> One hollow rifling bar with cutter, adjustment, and cutting tools.
> Milling cutters and mortice drills for milling and drilling machines.
> The total cost will be about $50,000.
>
> This plant is capable of producing one 6-inch gun per week, or a proportionally larger number of small calibers.
>
> (2.) COST OF GUN FACTORY PLANT UP TO 12-INCH CALIBER.
>
> This plant does not include rough boring and turning; the parts are supposed to be supplied ready for finishing. It includes:

One finish-turning lathe.
Three finish boring, turning, and chambering lathes.
One machine to cut breech-screw, &c.
One rifling machine.
One milling and drilling machine.
Four combined boring and turning face lathes for hoops.
One combined boring and turning face lathe for trunnion-hoops.
One combined boring and turning lathe for trunnions.
One slotting machine for trunnion-hoops.
One 40-ton power travelling crane.

Tools for the above, including—

Cast-iron tubes with steel head and cutter for finish-boring tubes.
Cast-iron tube with steel head and cutters for finish-boring jackets.
One chambering bar.

Fifty assorted turning tools for finish-turning lathes and machine for cutting breech-screw and spaces.

Cast-iron hollow rifling bar with cutter head, adjustments, steel tube for actuating tool, and cutting tools.

Four milling cutters and mortice drills for milling and drilling machine.

The total cost will be about $150,000.

This plant is capable of producing one 12-inch gun every three weeks, or a proportionally larger number of smaller calibers.

(3.) COST OF GUN FACTORY PLANT UP TO 16-INCH CALIBER.

This plant does not include rough boring and turning; the parts are supposed to be supplied ready for finishing. It includes:

Two finish-turning lathes.
Three finish boring, turning, and chambering lathes.
One machine to cut breech-screw, &c.
One rifling machine.
One milling and drilling machine.
Four combined boring and turning face lathes for hoops.
Four combined boring and turning face lathes for trunnion-hoops.
One combined boring and turning lathe for trunnions.
One slotting machine for trunnion-hoops.
One 100-ton power travelling crane.

Tools for the above, including—

Two cast-iron tubes with steel boring head and cutters for finish-boring tubes.

One cast-iron tube with steel boring head and cutters for finish-boring jackets.

One steel chambering bar.

Fifty assorted turning tools for finish-turning lathes and machine for cutting breech-screws and spaces.

One cast-iron hollow rifling bar with cutter head, adjustments, steel tube for actuating tool, and cutting tools.

Four milling cutters and mortise drills for the milling and drilling machines.

The total cost will be about $350,000.

This plant will produce one 16-inch gun per month, or a proportionally larger number of smaller calibers. In the room allotted to shrinking on the jackets and hoops, there will be required an additional travelling crane capable of handling guns of the heaviest weight, which will cost about $17,500.

From these estimates, the cost of equipping a gun factory capable of producing guns from the lowest caliber up to 16 inches, will be about $570,000.

If the tools mentioned above are to be made in the United States, these estimates would have to be largely increased, because there has been no demand to especially direct the attention of our manufacturers to them ; from this want of experience great delay and expense would result in the preparation of plans, specifications and patterns.

A wise policy would seem to demand that the tools required in this first plant should be purchased from those parties abroad who have had the most valuable experience in their manufacture.

III. Buildings.

At most of the establishments visited by the Board, the buildings have been constructed successively to meet increasing demands for space; and they therefore do not exhibit that systematic study which naturally would be demanded in planning a new gun factory. In such a problem the first step would be to decide upon the tools to be ordered, and their most convenient arrangement, and then the architect would be able to design the most suitable buildings.

As the Board will recommend that the manufacture of the metal and the fabrication of the guns shall be separately considered, and that the work shall be done at different localities, it has regarded the proposition of detailed plans for the buildings as inexpedient, not only because there would be little probability of their final adoption, but also because the time required for the estimates would materially delay the comple-

tion of the report. The subject, therefore, will be treated in a general manner. The following are the most important points developed by experience in Europe:

1st. Substantial foundations.

2d. Strong, but economical, superstructures secure against destruction by fire.

3d. Carefully considered lighting arrangements.

4th. Dimensions suited to the most convenient use of the tools, but which avoid waste space under cover.

Two distinct arrangements are in use abroad. In one, best illustrated by the new shops of Sir Joseph Whitworth, at Manchester (intended for general work), all the operations are performed under a single roof, a plan which has the merit of bringing all the workmen under the eye of the superintendent. The building has ten bays, each 50 feet wide, and at present 575 feet long, but it is proposed to extend this length 200 feet. Six bays are devoted to the foundry proper where the steel is manufactured and forged, and the remaining four to the tools used in fabricating the finished products. A gallery 25 feet wide extends along one side of the building forming a second story where small tools are made. Overhead cranes are provided, where necessary, to run the whole length of a bay, and the larger machines are disposed longitudinally under them. The height of the run-ways of these cranes is 22½ feet above the floor. Each bay is covered by a roof of 50 feet span and 18 feet rise. These roofs unite in valleys 8½ feet above the run-ways, to afford room for the cranes; and light is supplied by continuous windows, which, on the south side form the middle third, and on the north side the lower two-thirds of the roofs. The outer walls are brick. The bays are separated by rows of cast-iron columns capped with wrought iron trusses, on which rest the iron roofs.

These magnificent shops, constructed very recently, after Sir Joseph's long experience in such work, cost per running 50 feet of each bay:

Iron work of supports	$1250
Roof plating, glazing, glass, lead, &c	2000
Floors, plates, &c	1190
Contingencies	560
Total, per square 50 feet, about	$5000

Estimated upon this basis, given by one of the engineers, the total cost must have been at least $600,000.

In the other general arrangement of shops which prevailed at most of the establishments visited, different buildings are provided for different classes of work, with ample space between them for railway tracks, storage of metal, &c. Experience seems to have suggested the importance of the following points:

The run-ways of the large cranes should be supported quite independently of the buildings. As their spans vary from 40 to 64 feet, generally about 50 feet, this is an important matter. There is no economy in constructing the walls to bear strains thrown upon them by powerful machinery. The true function of the building is simply to cover the tools against the weather.

The problem of reducing the cost of roof trusses is an important one. For smaller machines, an economical and convenient arrangement was noted at the army establishment at Bourges. The building was about 260 feet long and 150 feet wide. Advantage was taken of the lesser height required for this class of work to dispense with roof trusses entirely. Cast-iron columns, about 17 or 18 feet apart, divided the whole interior into squares and furnished supports for the roof at so many points as to effect this object. The tools were disposed across the shop, and hand cranes overhead and medial railway tracks for cars supplied every facility for convenient handling. For the larger tools, however, the spans are necessarily so great that it seems expedient to increase their width so as to dispose the machines across the bays. This enables the arrangements to be very compact and enough is saved in length of shop to compensate for wide trusses. Thus, in the two new shops at Ruelle, which are good models, the span of the principal roof trusses are about 50 feet and 82 feet respectively, the total width of the buildings being extended by parallel and lower roofs to 98 feet and 130 feet.

Roof-lighting of gun-shops is general throughout Europe. Sometimes, as in Sir Joseph Whitworth's establishment, the ridge-pole is placed centrally between bearings, and one-third of the south and two-thirds of the north surface is glazed. At other places, as at the shop at Bourges just described, the ridge-pole is nearer the north side, and the short and steep

side of the roof only is glazed. Another plan is the common device of a ventilator cap over the ridge-pole, with vertical lighting. As a rule all available space at the sides and ends of the buildings are given up to windows. No gun-shops of more than one story were noted.

The Board would recommend the erection of fire-proof structures of a single story, designed solely to cover and protect the tools. Their style of architecture should be neat, but not extravagant; convenience of arrangements and facilities for lighting should receive careful study. It is believed that the cost of such buildings as are required can be safely estimated at $5000 per square of 50 feet." *

* Gun Foundry Board Report.

VIII.

GENERAL SUMMARY OF GUN FOUNDRY BOARD.

"The foregoing presents the chief points of information that have been gained by the investigations of the Board.

As examples of a practical partnership between a Government and a private company in working towards a national object the experiences in England and in Russia are very instructive, and warn against the adoption of such a system. In England, the Government, in addition to paying, during several years, very high prices for articles delivered, was forced to pay £65,000 to close an agreement; while the company, besides the profits on manufacture, came into possession of a complete working plant at a mere nominal valuation.

In Russia, the Government finds itself involved with a stock company, paying excessive prices for what it receives, and discovers no way of relief except by buying up shares and operating the establishment as a Government foundry.

As an example of depending almost entirely on private works, Germany is a perfect instance. The works of Mr. Krupp are practically the sole source of supply of the German artillery. In such a case the Government must be the slave of the corporation, and subject to its whims, caprices, and conveniences. It needs no argument to show the dependent condition ot the Government under such a rule: it might prove a source of the greatest embarrassment. The Board is well informed that some ten or eleven years ago the artillery officers were very restive under this load and were making strenuous efforts to be relieved from it, but without success. It is hardly to be supposed that time has quieted the feeling of dissatisfaction.

As an example of depending alone on Government works, France was a perfect instance before the Franco-German war. During the period referred to, the Government foundries were the sole source of supply of the armament of the country; the

officers charged with the work formed a close corporation; their action was never exposed to the public; their ideas were never subjected to criticism; the ingenuity and inventive talent of the country were ignored and resisted, and no precaution was thought necessary to provide a supply in case of need of re-armament. The result is well known; a great crisis came; the Government works were inadequate to meet the additional demands made upon them, and the patriotic efforts of private establishments were inadequate to produce all the material that was needed. How entirely France has now altered her system is shown in a previous part of this report; her present practice is theoretically perfect, and it has proved to be practically efficient. Her Government establishments are still retained, but as gun *factories* simply, in which the parts are machined and assembled, but for *foundry* work she depends upon the private industries of the country, and many of these works have found it to their profit to establish gun factories which supplement the Government factories to a great extent.

The conclusions of the Board on this subject accord with the plain teachings of these historical instances. It accepts the system now pursued in France as the proper standard for imitation, and recommends that in inaugurating the manufacture of war material in our own country a conformity as close as circumstances will admit to the plans which have proved so successful in France should be observed.

Having reached this conclusion, the Board is now prepared to dispose of the propositions into which, as stated on the seventh page of its report, the second interrogatory in the act of Congress was divided.

The first proposition was thus presented, viz.:

> That the Government should supplement the plants of some of the steel workers of the country with such additional tools and implements as would enable them to turn out finished steel cannon.

The adoption of this proposition would involve the Government in the embarrassments which now exist in Russia, and which we have seen were so costly to the English Government in its partnership with the Elswick Ordnance Company.

The Board does not approve of such joint action.

The second proposition was thus presented, viz.:

That the Government should give contracts of sufficient magnitude to enable the steel workers of the country to supply the finished guns without its direct aid.

This proposition, if adopted without any qualification, would make the Government dependent entirely upon the private industries of the country, which might combine to the detriment of the public service. The Government would have no guard against extortion and would be powerless against a combination. An actual instance of such a combination is cited in a previous portion of this report as having taken place in France, but the independent position of the Government made the effort futile.

The Board does not approve of this proposition taken by itself.

The third proposition was thus presented, viz.:

That the Government should establish on its own territory a plant for the fabrication of cannon, and should contract with private parties to such amounts as would enable them to supply from the private industries of the country the forged and tempered material.

This proposition is approved by the Board and is regarded as the foundation upon which our system of manufacture should be built up. If this be done, and the Government made secure by the possession of works of its own, there is every reason to adopt in addition the idea embodied in the second proposition in order to *supplement* the Government establishments.

A State, with any pretensions to military power, should provide itself with factory facilities on a sufficient scale to perform the work of establishing standards, making experimental guns and fabricating cannon on a moderate scale; but it is not considered judicious to concentrate in the Government establishments all the work of fabrication or to include within their operations the preparation of such material as can be provided by the private industries of the country. In the case under consideration the purchase of the steel required for cannon will stimulate our own manufacturers and interest them in the operations of the Government.

The Board is thus led to the conclusion that it is not advisable to embark in the establishment of a gun *foundry*, properly so called, but that it is more judicious to establish gun *factories*, and to purchase the material from our manufacturers.

At present the steel manufacturers of our country are not prepared to produce the material required for the larger calibers, and the important question arises, what means shall be adopted to induce them to study the subject and embark in the manufacture on a large scale. They cannot be expected to do this at a sacrifice of their own interests. This object can only be achieved by holding out a fair prospect of ultimate remuneration for the expenditures necessary to undertake the work, and this can only be done by the action of Congress.

If, then, Congress shall conclude to arm the country it will be necessary that a sum of money shall be fixed as a permanent yearly appropriation to be expended for this purpose, the amount to be assigned proportionately between the War and Navy Departments. With such a guarantee against loss the Board is satisfied that the required material for cannon will be forthcoming from our own steel works.

It would not be necessary for the Government to be associated with a large number of firms for the supply of its material, for it is probable that the private establishments that would take up the subject would only be those with large available funds which they would be willing to put into a special plant, and for remuneration on which they would be willing to wait a reasonable time. The permanent appropriation would give them surety of ultimate profit, the only condition being success in providing the material that would be indicated in their contracts. From personal intercourse with some of the leading manufacturers the Board is led to believe that the plan will have the effect of guiding the private industries of the country to the aid of the Government in developing this work of national importance.

This conclusion is fully sustained by letters, pages 567, 568, and by the following communication received from the Cambria Iron Company on February 8, 1884, after the completion of this report:

OFFICE OF CAMBRIA IRON COMPANY,
Philadelphia, February 7, 1884.

Commodore E. SIMPSON, U. S. N.,
President of Foundry Board.

DEAR SIR: Having received the impression that the Gun Foundry Board would, after its investigations in Europe, be prepared to give us some information that would assist in a reply to its circular letter of

May 1, 1883, we have delayed submitting any proposition that would indicate our "disposition to assist the object to be obtained," or an estimate of the manner and amount of "aid" required "from the Government."

We are now informed by the Board that such information cannot, without injustice to other private interests, be given before the publication of its report. We, therefore, have the honor to submit the following, suggested by our long and valuable experience in the manufacture of steel, and our investigations upon the subject-matter of the Gun Foundry Board's letter of May, 1883.

As requested in that letter, we have (as far as time would permit, and as carefully as possible without making a special visit to Europe) considered "the methods of manufacturing gun steel now employed in England, France, Germany and Russia, with a view to the selection of any of these methods for its manufacture." This careful consideration indorses the statement we have already made in person to your Board, that steel made by the open-hearth process is the most uniform; and that we believe we have the largest casting plant on this system in the United States, conducted by men of great experience. We further are of the opinion that our casting plant will meet the present requirements of the Government for gun metal, and if a sufficiently large contract or other guarantee against loss were given, we could rapidly develop it to meet increasing demands.

Like all other steel manufactories in the United States, we have no apparatus capable of forging the large ingots required for modern guns. Before embarking in a forging plant that must require an expenditure of from a quarter to a half million of dollars, we would await the opinion of the Board or the action of the Government in regard to the adoption of a hammer or a hydraulic press. We have been led to this conclusion by the great attention which is now given this question in England and the use of a hydraulic casting press in Russia; also, by the fact that a large number of shafts for English naval ships and a large quantity of steel furnished the Royal Arsenal and the works of Armstrong, Mitchell & Co., have been manufactured by Sir Joseph Whitworth, who casts and forges the steel for these purposes by hydraulic presses.

As the forging press is said to be cheaper and its effect equal to or better than the hammer, we would naturally adopt that method of forging, unless the Government in its contracts should require the metal forged with the hammer.

Our company has received invitations from the Ordnance Departments of both Army and Navy to furnish gun material, the castings for which are well within our capacity to make; but wanting a suitable apparatus to properly forge such castings, and in the absence of a sufficiently large contract to pay even the cost of small apparatus, and the risks attendant upon the development of a new branch of our industry, we did not deem it wise to undertake a small contract.

In regard to the problem you submitted, "Given your present plant, what aid would you require from the Government in order so to enlarge it as to be able to manufacture the heaviest ordnance, the work to include the entire process of manufacture from the casting of the ingots to the finishing of the gun," we have to state we have learned that England and France, two of the countries mentioned in your letter, separate the manufacture of the steel from the construction of the guns. As they have had long and valuable experience upon this subject it would seem that they have adopted this plan because it was the best.

In view of this fact we submit an approximate estimate of the amount to be expended to put our plant in a condition to supply the required steel for gun construction.

For the sum of $695,000 we could add to our present plant forging apparatus, tools to rough bore and turn, and appliances for tempering the material of such weight and sizes as we suppose the Government will demand. Of the above-named sum, $143,000 we estimate as duty at 45 per cent ad valorem on tools it will be necessary to import from foreign makers experienced in their construction.

We desire to call the attention of the Board to the following statement of business facts and considerations, that it may judge of the capacity, both financially and technically, of the Cambria Iron Company to undertake the work required of a national foundry.

The works of the company are located at a sufficient distance from the seaboard to render them absolutely secure from attack by a foreign enemy, while at the same time they do not occupy an isolated position so that communication between them and the exposed portions of the country would be either impossible or difficult for our own people. The works are situated directly on the main line of the Pennsylvania Railroad, which affords quick and safe communication between the East and the West, and also brings them within 80 miles of steamboat communication on the Ohio River at Pittsburgh. In addition to these transportation facilities, the works are also in direct rail communication with the Southern seaboard and the South itself by way of the Somerset and Johnstown Railroad, which is a thoroughly-built and well-equipped branch of the Baltimore and Ohio Railroad, which has eastern termini at Baltimore and Washington, and Southern connections at these and other points ; also a third trunk line between the seaboard and West, now under construction, passing a few miles south of Johnstown, and with which there will be direct connection. It may also be added that by way of the Pennsylvania Railroad and its connections at Harrisburg with the Northern Central Railway the works have an additional outlet to Baltimore, Washington, and the South.

The situation of the works of the Cambria Iron Company at Johnstown is one of great healthfulness, and it is comparatively sheltered from the extremes of both heat and cold, and is wholly free from all malarious influences, so that workmen can prosecute their various employments in

all seasons without danger of interruption from intense heat or cold, or from the prevalence of epidemics. The healthfulness of the situation of the works, the constant employment which has been given to its workmen for twenty-nine years, the cheapness of the necessaries of life, and the facilities which have been afforded by the company for the acquisition of homes by heads of families, have greatly contributed to the building up at Johnstown and in its immediate and dependent suburbs of a steady, sober, intelligent, and moral class of skilled mechanics—a fact upon which we desire to place great stress, as an industrial community that is fixed and permanent and attached by home ties and associations to its place of employment is far less likely to engage in contentions and strikes at critical periods than one that is composed of floating and uncertain elements.

The works have been in existence and in operation for more than thirty years, and in this time an army of skilled workmen has been gathered together that for efficiency, fidelity and variety of scientific and mechanical attainments, is believed to be unsurpassed, if equalled, in our whole country.

The works of the Cambria Iron Company are not merely of a reproductive or finishing character, but they embrace every branch of a complete establishment devoted to the manufacture of iron and steel. The company owns its coal mines, including extensive mines in the Connellsville coke region and other mines adjacent to the works at Johnstown; it owns its iron-ore mines, some of which are adjacent to the works, while others are situated in the Lake Superior region and elsewhere; it produces its own pig-iron in furnaces that possess all the modern improvements; it has a large Bessemer steel-plant, a large open-hearth steel plant, iron and steel rail and other rolling-mills, puddling and heating furnaces, wire mills, and facilities for the production of miscellaneous steel products.

The works have a capacity for the production of 300,000 tons of pig-iron and over 200,000 tons of steel per annum.

The company employs at the present time 9000 workmen. It has its own mining and mechanical engineers, its own draughtsmen, and its own chemists.

These details are mentioned to show the varied experiences of the employees and officers of the company; its perfect control over the raw materials it uses, and consequently over the character of all its products, and the facilities generally for the prompt addition to its works for the contemplated national foundry, and the equally prompt and faithful execution of such orders as would be required of it.

It only requires to be added that the financial ability of the Cambria Iron Company to comply with all its engagements cannot be questioned. . . . It owns absolutely all of its property, without intervening creditors, as it has no bonded nor floating debt; all its employees are regularly paid every month; it can always manufacture all the articles

it now produces as cheaply as any of its competitors, and hence is in no danger of ever abandoning business as a manufacturer of iron and steel. If financial ability to execute a contract is desirable, then the Cambria Iron Company may truthfully be said to possess that requirement in an eminent degree; and if a reputation for energy, enterprise, conscientiousness, and complete success in the production of iron and steel of the best qualities counts for anything, the Cambria Iron Company, it may also be truthfully said, possesses this reputation and has possessed it for many years.

In conclusion, we desire to inform the Gun Foundry Board that the Cambria Iron Company may be induced to undertake at once the development of its steel plant to meet the requirements for gun material if the United States Government will make a sufficiently large contract or give other positive guarantee which shall insure the Cambria Company adequate employment or sufficient profit to reimburse this large expenditure, the company on its part undertaking to meet the required tests.

If the Government desires to enter into any joint action by furnishing the means for the development of a plant, with a reserve for reimbursement, the foregoing statements indicate our ability to undertake such action under the most favorable conditions for the faithful execution of the work.

All of which is respectfully submitted.

CAMBRIA IRON COMPANY,
By E. Y. TOWNSEND, *President.*

It may be added that although the manufacture of armor-plates for ships and fortifications was not referred to this Board for investigation, the erection of plant for providing modern cannon would go far towards reducing the outlay requisite to enable our great steel manufacturers to meet another pressing want of the Government.

The chief expense to be considered by private parties is that of the *forge*, but by the substitution of the hydraulic press for the hammer, economy will be consulted and better results obtained. The Board is unanimous in approving the use of the press for all forging purposes; and recommends it to all who may embark in the manufacture of gun metal for the Government.

In conclusion the Board submits its replies to the three interrogatories contained in the act of Congress:

(1.) Which of the navy yards or arsenals owned by the Government has the best location, and is best adapted for the establishment of a government foundry?

The Board does not recommend the establishment of a government foundry, properly so called, which shall provide for the manufacture of steel and the fabrication of cannon. It considers that every inducement should be offered to attract the private industries of the country to the aid of the Government in providing ordnance for the Army and Navy, and that the steel manufacturers should be called upon to provide the material.

The Board recommends the establishment of two gun factories under the control of the Government and selects the—

Watervliet Arsenal, West Troy, N. Y., as the site for the Army, and the

Washington Navy Yard, District of Columbia, as the site for the Navy.

The Board is unanimous in recommending that the Army and the Navy should be provided with separate establishments. This has always been the custom in France, producing good results; the reverse has been the practice in England, producing bad results. Dissatisfaction from this cause has existed for many years in the English navy, and the Admiralty has recently brought about a revolution in the system so far as the supply of gun-carriages is concerned, by obtaining from Parliament a separate and distinct appropriation with which it is providing the English Navy with the Vavasseur gun-carriage in opposition to the will of Woolwich.

In the administration of the War and Navy Departments of the United States, each service has charge and direction of its own distinct system of artillery; hence if but one gun factory be provided, its control must be placed in the hands of a mixed commission. This must lead to conflict of authority and to embarrassments of all kinds, in which the heads of Departments must necessarily become involved. A close scrutiny of the practical difficulties that would arise in conducting the affairs of a gun factory in such mixed interests develops obstacles that would be insuperable even with the most harmonious intent.

In the selection of the sites mentioned, it is not intended to convey the idea that they are regarded as in every way adapted for the purpose, but, as the scope for choice is limited, they are considered the most advantageous. The Board does not recommend the purchase of new sites, as this would open

so wide a field for selection as to embarrass the question by arousing local interests throughout the country.

(2.) What other method, if any (apart from the establishment of a Government foundry), should be adopted for the manufacture of heavy ordnance adapted to modern warfare, for the use of the Army and Navy of the United States?

With Government gun *factories* established for both the Army and the Navy, there will be still needed the hearty co-operation of the private industries of the country. This cannot be aroused unless there is held out to them a fair prospect of remuneration. The Board does not approve of a partnership in business between the Government and private firms. *All history warns against such a course.* But it does believe that joint, and at the same time independent, action between them can be made to work harmoniously towards the common national purpose. This can only be done by a permanent and liberal appropriation by Congress for the specific purpose of providing the country with modern artillery; which appropriation shall be a guarantee against loss to the companies who elect to undertake the work.

This is entirely consistent with the action of Congress in providing for the supply of arms to the militia. The act authorizing this practice was passed in 1808 and since that time the yearly disbursement has been made from the Treasury without interruption. A similar act providing for the supply of heavy ordnance for the regular services will be but a farther development of the same idea.

(3.) The cost of all buildings, tools and implements, necessary to be used in the manufacture thereof, including the cost of a steam-hammer or apparatus of sufficient size for the manufacture of the heaviest guns.

In reply to this question the Board presents an abstract of the information already given, arranged in a convenient form for reference.

Approximate cost of plant for producing the tempered parts of guns up to 100 tons, ready for delivery at gun factory:

Casting	$250,000
Forging (hydraulic press)	150,000
Rough boring and turning	210,000
Tempering	50,000
Total	660,000
Additional cost if liquid compression be adopted	175,000

Approximate cost of plant for gun factories:

Guns up to 6-inch caliber	50,000
Guns from 6-inch to 12-inch caliber	150,000
Guns from 12-inch to 16-inch caliber	350,000
Buildings and shrinking pit	350,000
Total	900,000

Three years will be required to complete the tools, construct the shops, and establish the plant. Such a factory will be able to turn out per year fifty 6-inch, seventeen 12-inch, and twelve 16-inch guns, or a proportionally larger number of smaller calibers, at a yearly expense of about $2,000,000. The figures cannot be pronounced exact, but the Board is confident that they closely approximate accuracy. The calculations are based upon estimates obtained abroad, and do not include ocean freight and customs dues."*

Under date of May 10, 1882, Colonel Crispin, U. S. A., reported the cost of steel construction, as afforded from European sources, as:

Krupp	51 to 60 cents	per pound.
Whitworth	38	"
Woolwich Guns	30½	"
24-cent. steel land service guns (France)	48	"

The price of French steel construction has been greatly reduced.

"Though the Act of Congress replied to in the above report is one of inquiry, the Board desires to emphasize the necessity of a proper encouragement to the private steel manufacturers, which shall insure the supply of gun material without loss to the Government or private companies; and is of opinion if Congress shall be pleased to appropriate an adequate sum for providing modern artillery for the Army and Navy, to be held in the Treasury to be expended under the authority of the President, that (with such a prospect of remuneration) there are steel manufacturers in the United States who will undertake the production of gun-metal on a large scale, on the sole condition that their steel shall meet the required tests. Unless such action be taken, the Government will be compelled to purchase its gun-metal abroad, for it will be unreasonable to expect private parties to invest over half a million dollars in plant without a definite prospect for its employment.

* Gun Foundry Board Report.

The facts that the United States is destitute of the means of fabricating the modern guns so urgently needed for national defence, and that at least three years will be required to complete the tools, construct the shops and establish the plant, would seem to demand an immediate appropriation of the amount ($1,800,000) estimated for the establishment of the proposed gun factories.

E. SIMPSON,
Rear-Admiral, United States Navy, President of the Board.
E. O. MATTHEWS,
Captain, United States Navy.
T. G. BAYLOR,
Colonel of Ordnance, United States Army.
HENRY L. ABBOT,
Lieutenant-Colonel of Engineers,
Brevet Brigadier-General, United States Army.
SAM'L S. ELDER,
Major, Second Artillery, United States Army.
W. H. JAQUES,
Lieutenant, United States Navy,
*Member and Secretary of the Board."**

* Gun Foundry Board Report.

IX.

CONCLUSION.

"We should also provide for making guns and armor of the heaviest kind and of the best pattern and of the strongest metal. If we had the vessels, we could not now, ourselves, arm them ; for we have to send to England or Germany for steel castings for guns of over 6-inch bore, and 18-inch may be required. Our best seacoast guns are harmless against such iron-clad ships as European nations could send into our Atlantic ports in two weeks. The commonest prudence and safety should lead our Government to establish and perfect works, and train up skilled artisans, at some well-located yard, till it can produce at least as heavy and effective ordnance as any other nation.

"In the meantime we should provide abundant means for the defence of all our harbors, as monitors, torpedoes, and fortifications for these guns as soon as we can make them.

"*Resolved*, That it is the duty of Congress to provide for adequately defending our harbors, both ocean and lake, and for the construction of vessels of war, guns, and armor of the highest type, and on a scale sufficient to insure the common defence and overcome any attacks by foreign nations." *

The report of the Gun Foundry Board was laid before the House of Representatives, February 20, 1884, during the discussion of the Naval Appropriation Bill, but received no consideration, notwithstanding the urgent appeal of the Secretary of the Navy for an appropriation to procure modern high-powered cannon, and the statement of the Chief of Ordnance, Navy Department, that

> It is hardly probable that the utmost exertions of this bureau could result in the completion of the armament of the steel cruisers in time for the ships, even if every facility were afforded and all orders could be placed without the least delay.

* Report and Resolutions of Union League Club, New York, December, 1883.

It has been foreseen from the first that the design and manufacture of the guns and their material would entail more difficulty than that of the ships themselves, and therefore it seems doubly unfortunate that the appropriation for the batteries should be omitted at a time when it is so very much needed.

It is not enough to arm simply these steel ships with modern ordnance, but the obsolete cannon and material on the ships that carry our flag on the various cruising stations should be changed as soon as possible. At present these ships are at an immense disadvantage as compared with those of foreign nations they meet abroad, and we are bound not to let such a state of things exist a moment longer than is absolutely necessary.

In the Senate, in reply to the inquiry of Mr. Morgan, of Alabama, as to what was being done in the manufacture of modern guns, Mr. Hale, Acting Chairman of the Committee on Naval Affairs, called his attention to the report of the Gun Foundry Board:

It is a very exhaustive report. It is full of the most interesting facts and details, and it places before the country as has not been done before, just the situation that we are in with relation to the manufacture of ordnance for our Army and our Navy.

It was a joint board made up of well known skillful officers of the highest standing and with the best records. They visited the manufactories of arms in the Old World, and have made a very carefully prepared report, showing just what the situation is as to this matter.

In further reply to Mr. Morgan's statement that

The commission that has been spoken of by the Senator from Maine went abroad last summer, I believe, and also made some explorations through the United States for the purpose of examining into the different ordnance establishments or the different iron and steel establishments capable of manufacturing guns. It submitted a report, which I have not had the opportunity to examine with any care. I have merely glanced through it. But I understand that they recommend now that we shall go on in the old grooves and look abroad for our steel; that we shall not begin now to build establishments for the purpose of making steel or for the purpose of working steel.

Mr. Hale continued:

The Senator, I know, has given a great deal of time and has an intelligent interest in this subject. I wish he would take this report, if he can, to-night, look it over carefully, and see what he for one, as a member of this body, is ready to do in the way of embarking in this enterprise of governmental establishments that can manufacture an entire gun. This is a serious question. It is a serious question whether the Government shall grapple with that problem. It cannot be done without involving in the future an expenditure of a large sum of money. I am entirely ready to go with the Senator to any extent in so expending money, for I believe with him that there is something culpable, something criminal in the hap-hazard, easy-go-lucky way that we are going on

at present with reference to our national defence. But whoever sets out on this road, whoever weds himself to this enterprise, has got to consider that from time to time large sums of money will be required. If the American Congress is ready to appropriate those sums of money and will follow its hand and will not falter, but from year to year will, almost in the nature of a permanent appropriation, give those sums of money, we shall reach that point so much desired by the Senator of Alabama—of the United States manufacturing all its guns, great and small.

As I have said, I will go with him very far in that direction. The board that considered this subject, as the Senator will find when he comes to examine the report, go into it very thoroughly. They do not arrive at the conclusion that the United States, either by governmental factories or by private means, should not manufacture these guns. Quite the reverse. They say clearly :

The board recommends the establishment of two gun factories under the control of the Government.

And it makes a selection. Then it goes on touching the question whether the Army and the Navy each should have an establishment, and arrives at the conclusion that an establishment for each branch of the military force of the Government should be set up and maintained, one for the Army and one for the Navy. They go on further and say:

With Government gun factories established for both the Army and the Navy, there will be still needed the hearty co-operation of the private industries of the country. This can not be aroused unless there is held out to them a fair prospect of remuneration. The board does not approve of a partnership in business between the Government and private firms. All history warns against such a course. But it does believe that joint, and at the same time independent, action between them can be made to work harmoniously toward the common national purpose.

The board found this difficulty when it began to deal with the question of encouraging private establishments, such establishments as are found in great force and strength in the old world under the enterprising head of men of genius who have built them up. The board found themselves confronted with this trouble, that the private manufacturer in this country can not afford to go on, extend his plant, build up his establishment, because of the uncertainty whether the Government will come to his rescue and employ him to make guns, or encourage him to make guns, or a portion of the guns, for any length of time. They say:

At present the steel manufacturers of our country are not prepared to produce the material required for the larger calibers, and the important question arises, what means shall be adopted to induce them to study the subject and embark in the manufacture on a large scale. They cannot be expected to do this at a sacrifice of their own interests. This object can only be achieved by holding out a fair prospect of ultimate remuneration for the expenditures necessary to undertake the work, and this can only be done by the action of Congress.

Everybody sees that however enterprising, however patriotic may be the owner of one of these private establishments, however much he may be willing to extend his plant and increase his establishment, he ought to feel that he can

depend upon something like a permanent policy on the part of the Government in encouraging him. The English Government, the French Government, the German Government, the government, indeed, of every power in Europe that makes any essay toward establishing and maintaining a naval force, appropriates money by millions year after year, and it is because of this that the great establishments there that are the wonder of the world are kept up from year to year, knowing as they do that the governments will patronize them in that part of the world in the manner that they do. But it costs money, and a great deal of money, as I have said. If the Government has establishments of its own, which in connection with private establishments can make these great guns, as I believe it ought to have, and I am ready to vote large sums of money to that end, it ought to contemplate what it is going into; it ought not to set its hand to the plow and then go back; it ought to go steadily on appropriating money out of our surplus revenue. The board wind up by these wise and pertinent words and conclusions:

Three years—

After estimating the cost of these factories and plants—

Three years will be required to complete the tools, construct the shops, and establish the plant. Such a factory—

Costing $900,000—

Such a factory will be able to turn out per year fifty 6-inch, seventeen 12-inch, and twelve 16-inch guns, or a proportionally larger number of smaller calibers, at a yearly expense of about $2,000,000. The figures cannot be pronounced exact, but the board is confident that they closely approximate accuracy. The calculations are based upon estimates obtained abroad, and do not include ocean freight and customs dues.

If Congress is ready to embark in this enterprise of building up for the Government a great gun factory and a great plant for preparing guns for the gun factory, so that our steel shall be taken and made into the tube and the tube shall be taken and wrought into the gun, and so that we shall not stop at an 8-inch gun or a 12-inch gun, at nothing short of a hundred-ton gun, I am ready to go along in that direction.

In reply to Mr. Bayard's reference to his resolution directing the Committee on Naval Affairs "to report upon the expediency of building a steam-hammer with a foundry properly equipped for the construction of artillery of the largest caliber and of modern fashion," Mr. Hale added:

I want to say one thing further in answer to what the Senator urges as to the resolution that he sent to the Naval Committee. It did, as the Senator intended, raise this whole question of the advisability, the feasibility of the Government building a gun factory and building a hammer of its own to make guns. Since the Senator introduced that resolution, the report of this Board, from which I have been reading, has been sent in to the Senate by the President, his message accompanying the report, and the Naval Committee has felt

that no investigation by it could add anything to the valuable mass of information contained in that document. I do not believe that we could have produced information that would have thrown any light on this subject, in answer to the Senator's resolution, equal to that. That is the reason why we have done nothing more.

The following amendment was offered by Mr. Hale, but afterward withdrawn, in the belief that the forgings for gun tubes, jackets and hoops should be, as the Gun Board conclude in their report, produced by private enterprise, which should be encouraged:

For the purchase and erection of plant for casting, forging, rough-boring, and tempering guns up to one hundred tons, ready for delivery at gun factories, including cost of the process of liquid compression, if adopted, $835,000.

Mr. Hale also reported the following:

For plant for gun factory for completing guns from 6-inch caliber to 16-inch caliber, including buildings and shrinking-pit, $900,000.

Mr. BAYARD. The amendment of the Senator from Maine is in the line of a proposition which I entirely approve, and that is that the Government of the United States should, after this very long interval of neglect, commence the preparation of some facilities for the construction of modern artillery. I have read with some interest and care the report of the Gun Foundry Board, to which my attention was directed by the Senator from Maine, to be found in House Executive Document No. 97 of the present session. I have read it carefully, and it seems to be most intelligently stated. The result of their recommendations is in some degree embodied in the two amendments presented by the Senator from Maine; but he has not presented them subject to the conditions that the Board recommend. At page 47 of the report, after criticizing the English, the French, and the Russian systems of constructing artillery, they state the conclusions of the Board, as follows:

The conclusions of the Board on this subject accord with the plain teachings of these historical instances. It accepts the system now pursued in France as the proper standard for imitation, and recommends that in inaugurating the manufacture of war material in our own country, a conformity as close as circumstances will admit to the plans which have proved so successful in France should be observed.

The plan in France was this:

As an example of depending alone on Government works, France was a perfect instance before the Franco-German war. During the period referred to the Government foundries were the sole source of supply of the armament of the country; the officers charged with the work formed a close corporation; their action was never exposed to the public; their ideas were never subjected to criticism; the ingenuity and inventive talent of the country were ignored and resisted, and no precaution was thought necessary to provide a supply in case of need of rearmament. The result is well known: a great crisis came; the Government works were inadequate to meet the additional demands made upon them, and the patriotic efforts of private establishments were inadequate to produce all the material that was needed. How entirely France has now

altered her system is shown in a previous part of this report; her present practice is theoretically perfect, and it has proved to be practically efficient. Her Government establishments are still retained, but as gun factories simply, in which the parts are machined and assembled, but for foundry work she depends upon the private industries of the country, and many of these works have found it to their profit to establish gun-factories which supplement the Government factories to a great extent.

That makes the recommendations of the Board obviously wise, and the Government by having gun factories of its own as well as other plant for making the raw material, will never be subject to extortion by private contractors, because, unless they shall propose to do their work upon fair terms, the Government will have the ability to turn to its own facilities and prevent its suffering at their hands.

On page 50, however, we come to the conclusion of the report signed by this Foundry Board. They state the cost of casting, forging (hydraulic press), which it seems by the late experience is preferred to the steam-hammer process of forging, rough boring, and turning, and tempering, and the approximate cost of plant for gun factories to be found in this document, the one at $775,000 and the other at $900,000. But they say:

Three years will be required to complete the tools, construct the shops, and establish the plant. Such a factory will be able to turn out per year fifty 6-inch, seventeen 12-inch, and twelve 16-inch guns, or a proportionally larger number of smaller calibers, at a yearly expense of about $2,000,000. The figures can not be pronounced exact, but the Board is confident that they closely approximate accuracy. The calculations are based upon estimates obtained abroad, and do not include ocean freight and customs dues.

* * * * * *

The facts that the United States is destitute of the means of fabricating the modern guns so urgently needed for national defence, and that at least three years will be required to complete the tools, construct the shops, and establish the plant, would seem to demand an immediate appropriation of the amount ($1,800,000) estimated for the establishment of the proposed gun factories.

That is to be the total cost of these two establishments which have been suggested by the amendment of the Senator from Maine. It is obvious that if three years are required, installments of one-third of the amount stated should ratably be appropriated as time goes on. But, Sir, there ought to be something more before this money is appropriated; there ought to be something more than mere approximation. There can be and there ought to be an examination, and a detailed examination, and drawings and estimates, in order to ascertain how much of this $2,000,000 in round numbers will be needed in each year to commence and carry on economically the proposed structures.

I am strongly in favor of this appropriation when we have put it under the proper restrictions, under estimates in detail; and it is a strange thing that it has been so long delayed. It is proper that it should be immediately commenced, and economy will dictate that preparation for the commencement is essential. We must know more about it than we can in this way and by this amendment. I ask to have read for information that which I would propose as a substitute for these two amendments; but I apprehend that both the amendments will be withdrawn by the Senator from Maine, because they are not in

order on this bill. The point has been suggested by the Senator from Kentucky as to one, and it will be as to the other, for it was only withdrawn to allow an explanation. If the Senator will allow my proposition to be read, perhaps he will agree with me in permitting this amendment, which appropriates no money, but directs examination to be made, to be incorporated in the bill.

Mr. HALE. I presume the Senator and I will come to an accord on this matter, because we are seeking a common end. I have already withdrawn one amendment, and only the second one now remains. I shall be glad to hear what the Senator proposes.

Mr. BAYARD. I ask that my amendment be read for information.

The PRESIDING OFFICER. The amendment of the Senator from Delaware proposed as a substitute will be reported.

The Chief Clerk read as follows :

That it shall be the duty of the Secretary of the Navy, with the assistance of the naval advisory board, appointed in conformity with the act approved August 5, 1882, to report to Congress on the first day of the next ensuing session a plan and estimate for the preparation and purchase of plant for a gun factory to complete guns from 6-inch caliber to 16-inch caliber, including buildings and shrinking-pit ; also for purchase and preparation of plant for casting, forging, rough-boring, and tempering guns up to one hundred tons ready for delivery at gun factories, including machinery for liquid compression ; and to report the full and detailed estimates for the cost of the work aforesaid, and whether the same can be better and more economically performed in establishments owned by the Government, or by private contract, or by a combined system whereby the said work can be accomplished partly by the Government and partly by private contract, and in what annual installments the said appropriation can most economically be made.

Mr. HALE. So far as I see I am entirely willing to withdraw the other amendment and accept this amendment that has been submitted, or will be, by the Senator from Delaware. It is in the line of a more complete investigation of this important subject. The Gun Board does not believe in the Government erecting what is provided for in the second part of the Senator's amendment, but he has well provided in that for the whole question to be considered. The report that we get under this will, if anything can, throw additional light. And directly in point here I ask that there may be printed in the RECORD a letter from the Secretary of the Navy on this subject, inclosing a letter to him from Admiral Simpson, who was at the head of the Gun Foundry Board.

The PRESIDING OFFICER. If there be no objection the letters will be printed in the RECORD. The Chair hears no objection.

The letters are as follows :

NAVY DEPARTMENT, *Washington, April* 10, 1884.

SIR : I have the honor to enclose a copy of a letter from Rear-Admiral Edward Simpson, president of the Gun Foundry Board, relative to the amendments proposed by you to the naval appropriation bill for providing means for the manufacturing within the United States of material for heavy cannon and for the fabrication of naval guns from such material. I concur with the Board in advising that private works should be induced to produce the necessary steel by contracts involving a fixed annual appropriation continued for a series of years, and that the guns should be fabricated at Government factories.

As the subject is novel, and any appropriations for these objects will be large, I recommend that there be added a requirement that the sums shall be expended only with the assistance and advice of a board appointed by the President after confirmation by the Senate, three members of which at least shall consist of naval officers.

Very respectfully,

WM. E. CHANDLER,
Secretary of the Navy.

Hon. EUGENE HALE,
Acting Chairman Naval Committee, United States Senate.

NAVAL ADVISORY BOARD, *Washington, April* 9, 1884.

SIR: Referring to an amendment to the naval appropriation bill "reported for information" by Senator HALE in the Senate, which provides for the manufacture of metal for cannon at Government expense, I ask your attention to the following conclusions arrived at on this subject by the Gun Foundry Board:

The Board concluded that the Government should fabricate the guns at gun factories.

The Board concluded that the manufacture of the material, including casting, forging, rough boring and turning, and tempering, should be done by private works.

The amendment reported yesterday is opposed to the mature conclusions of the Board, which desired this encouragement given to the private industries of the country.

In order to encourage this outlay of private funds, the Board proposed a permanent appropriation (similar to that for supplying arms to the militia) for "providing the country with modern artillery." This appropriation would be a guarantee against loss to those who undertake the work.

The proposals of the Board would thus involve—

1. Nine hundred thousand dollars for the establishment of a complete Government gun factory for the Navy.

This includes the fabrication of guns of the largest calibers. So far as the Navy is concerned, the plant for guns from 12-inch to 16-inch calibers might be omitted at present; guns up to 12-inch caliber is all we will require for some time. This would reduce the amount of the appropriation to $550,000.

2. To keep the full plant, including that for 16-inch caliber, busy (producing fifty 6-inch, seventeen 12-inch, and twelve 16-inch guns yearly) a permanent yearly appropriation of $2,000,000 will be required. Leaving out the guns from 12 to 16-inch calibers would reduce that amount about one-half, say to $1,000,000.

If half of this amount be estimated for labor at the gun factory and half for purchase of material, the private manufacturers will have the guarantee of $500,000 yearly to remunerate them for the expense of putting up a plant for preparing the material for guns for the Navy alone.

I would recommend as a substitute for the amendment referred to, the following:

"For the purpose of providing modern artillery for the Navy of the United States, for the purpose of encouraging in the United States the manufacture of material suitable for modern artillery, and for the purpose of establishing a guarantee against loss to those manufacturers in the United States who will undertake the manufacture of suitable material, $1,000,000, to be a permanent yearly appropriation to be expended under the authority of the President for the specific purposes cited.

"For plant for gun-factory for completing guns embracing all calibers up to twelve inches, including buildings and shrinking-pit, $550,000."

I feel confident with such a guarantee the material for cannon will be

forthcoming from our own steel-works. I believe that the Cambria Works at Johnstown would entertain the idea seriously and at once.

Very respectfully,

E. SIMPSON,

Rear Admiral, United States Navy, President of the Gun Foundry Board.

Hon. W. E. CHANDLER,

Secretary of the Navy.

Mr. HALE. I withdraw my amendment.

During the discussion of Mr. Bayard's amendment, various changes were made until the following was finally agreed to:

That it shall be the duty of the Secretary of War and the Secretary of the Navy, with the assistance of the Gun Foundry Board, which is hereby revived, to report to Congress on the first day of the next ensuing session a plan and estimate for the preparation and purchase of plant for a gun factory to complete guns from 6-inch caliber to 16-inch caliber, including buildings and shrinking-pit; and to report full and detailed estimates for the cost of the work aforesaid, and whether the same can be better and more economically performed in establishments owned by the Government, or by private contract, or by a combined system whereby said work can be accomplished partly by the Government and partly by private contract, and in what annual installments the said appropriation can most economically be made.

In the consideration of the Senate amendments by the House of Representatives, Mr. Talbott moved that Mr. Bayard's amendment should be concurred in; but, after considerable discussion, withdrew his formal amendment.

The amendment, however, was accepted in conference committee, and the Gun Foundry Board reconvened May 15, 1884, commenced the preparation of detailed plans and estimates for two steel gun factories, one for the Army and one for the Navy, and sent the following to the steel manufacturers of the United States:

GUN FOUNDRY BOARD,

NAVY DEPARTMENT,

WASHINGTON, D. C., *May* 15, 1884.

GENTLEMEN:—There is forwarded to you herewith a copy of the report of the Gun Foundry Board, organized by order of the President, April 2, 1883.

The report has been favorably received by Congress, and the Board is again in session for the purpose of supplying supplementary information looking towards the development of gun factories for the Army and the Navy.

In addition to what is contained in the report, your attention is particularly called to the following paragraph, included in the order under which the Board is now acting:

"In case the Board shall be of opinion that the manufacture of the necessary gun material should be developed in this country by contracts with American manufacturers, the Board may communicate with and receive proposals from such manufacturers; and will cause to be prepared and submitted

suitable contracts in detail, ready for execution, in case they shall be approved by Congress, and will make specific recommendations concerning the same."

The Board is also directed to report "in what annual installments appropriations can most conveniently be made."

You will see from the report that the Board is very decidedly of opinion that the gun material should be developed in this country, and the object of now addressing you is to request from you such proposals as may guide the Board in its recommendations as to the annual appropriations to be made. You are requested to consider the classes presented under the head of "Cost of Plant for the Manufacture of Guns," on page 40 of the report.

There will be required for the largest guns a capacity for casting an ingot of 100 tons. For 12-inch and for 6-inch guns there will be required a capacity for casting ingots of about 30 tons and 5 tons respectively.

For forging these masses, there will be required a hydraulic press, with its accessories ; for the largest castings, one of 36-inch diameter will be necessary ; but for the smaller ones, presses of reduced power and cost may be substituted.

For rough boring and turning, there will be required a plant, as shown on page 41 of the report.

For tempering, there will be required a suitable furnace and tank.

All the above operations will be required at the foundry before the parts will be received at the gun factories, and estimates of the cost of the appliances are stated in the report.

In whatever particular your works may be deficient in the appliances required above, you are requested to consider the outlay necessary to efficiently equip your establishment, and to determine the size of contract for annual supply of gun material for a term of years, that will justify you in incurring this expense for plant, your remuneration to be derived solely from the price paid by the Government for the material after passing the tests required.

As this subject is now before Congress, you are requested to provide the information asked for, at your earliest convenience. In considering the matter of a plant for the manufacture of gun material, the Board suggests that you do not lose sight of its availability for the manufacture of armor, for which a call may be made by the Government.

Very respectfully,

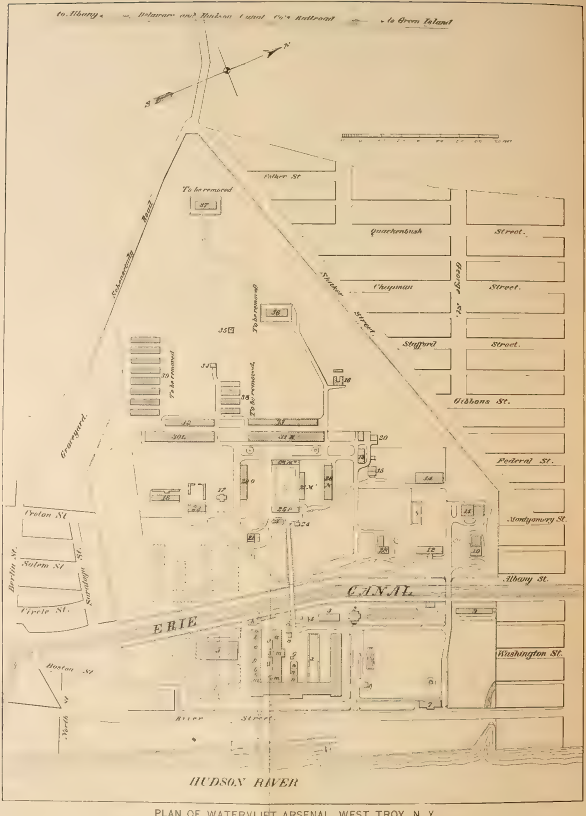
E. SIMPSON,

Rear-Admiral, U. S. Navy, President of the Board.

In the selection of the sites for the two gun factories, the Board chose those that were considered the most advantageous.

Watervliet Arsenal.—This arsenal is situated in West Troy, New York, and comprises 109 acres, portions of which are occupied at present (Plate LXXVII.), as follows:

1 Guard House.
2 Office.
3 Qr. Mr. Office and Engine House.
4 Store-house.
5 Iron Store-house.
6 Work Shops.
  a Smith.
  b Finishing.



PLAN OF WATERVLIET ARSENAL, WEST TROY, N. Y.

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2 Office.
3 Qr. Mr. Office and Engine House.
4 Store-house.
5 Iron Store-house.
6 Work Shops.
  a Smith.
  b Finishing.

c Carriagemakers and Carpenters.
d Paint.
e Foundry.
g 2d Story, Armorer's.
h 2d Story, Saddler's.
k 2d Story, Polishing and Brazing.
m Turbines.
n Boiler and Engine Rooms.
x Foundation for New Smith Shop.
7 Brick Arsenal.
8 Coal Yards.
9 Laboratory.
10 Officers' Quarters.
11 " "
12 Stone Arsenal.
13 Com'd'g Officers' Quarters.
14 Artillery Store-house.
15 Cottages for Enlisted Men.
16 " "
17 " "
18 " "
19 Brick Stable.
20 " "
21 Hospital.
22 Barracks.
23 Ice House.
24 " "
25 P. Nitre Store.
26 Timber Store-house, *N*.
27 " " *M*[1].
28 " " *M*[2].
29 " " *O*.
30 " " *K*.
31 " " *L*.
32 Carriage Shed, Temp'y.
33 " "
34 Proof House.
35 Tank House.
36 East Magazine.
37 West "
38 Carriage Sheds.
39 " "

The river front is 1600 feet long, 800 feet of which is finished as a stone wharf where vessels as large as any navigating the upper Hudson can unload. From the river it extends westward with a width of 1700 feet to the Erie canal (passing through about 600 feet from the river), and thence in triangular shape to a point about 1000 feet from the canal and within 300 feet of the track of the Delaware and Hudson Railroad, with which an easy and inexpensive connection would afford direct communication with the Albany and Susquehanna, Rensselaer and Saratoga, Hudson River, New York Central, Troy and Boston, and Boston and Albany Railroads, and provide abundant means of transportation for supplies and products.

The Erie Canal and Hudson River also furnish their best facilities for water transportation, west and south; so that, for the movement of every variety of freight in any direction, all the best known means are at hand.

The city of New York (within four and a half hours by rail and ten hours by water) offers the advantages it affords for supplies of material, of labor, and external shipping. Thus, while almost within the city limits for peaceful purposes, for military protection and security this site is in the valley, equidistant from the ocean and the lakes, and guarded from the attack of an enemy by a long line of march from either.

Receiving without probable interruption and with facility all material that may enter the chief ports, or be gathered from our fields, in time of war, it can safely distribute by interior roads its completed productions to every exterior point of defence—itself undisturbed—even should an enemy's fleet command our whole Atlantic coast.

The neighborhood possesses skilled labor to an unusual extent and variety.

It is in direct and most convenient water communication with the *proving-ground* at Sandy Hook, New Jersey.

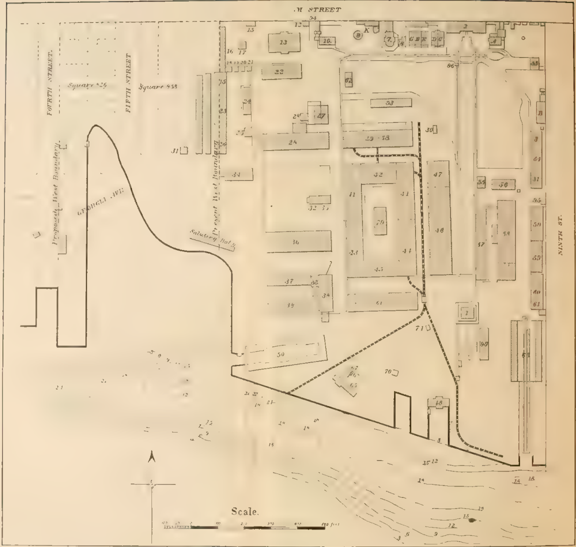
While there exist no private works in sufficient proximity to threaten abscrption, the ground west of the Erie Canal, beyond the present limits of the arsenal, is almost without settlement, rendering possibility of expansion easy and certain.

The character of the foundation is excellent; in salubrity of climate and in agricultural resources, the neighborhood is equal to any, so that no local advantage is wanting to fit it for the purpose.

The site thus appears to meet all the requisites, page 555, of location and adaptability.

Washington Navy Yard.—This navy yard is situated in the District of Columbia, on the eastern branch of the Potomac River, and comprises 42 acres, portions of which are occupied at present (Plate LXXVIII.), as follows:

A Officers' Quarters.
B " "
C " "
D " "
E " "
F " "
G " "
H " "
1 Commandant's Office.
2 Main Gateway Building.
6 Dispensary.
7 Civil Engineer's Office.
8 Naval Store.
9 Ice House.
10 Museum.
12 Stable.
13 "
15 Packing House.
16 Ordnance Store.
17 Fulminate House.
18 Mixing "
19 Finishing "
20 Rocket "
21 Cap-filling "
22 Shell "
23 Ordnance Store.
24 Laboratory.
25 Magazine.
26 Ordnance Stores.
27 " Foundry.
28 " Machine Shop and Boiler House.
29 Iron Foundry.
30 Coal Shed.
31 Rocket Press House.
32 Acid House.
33 Stables.
34 Gun Carriage Shop.



PLAN OF NAVY YARD—WASHINGTON, D. C.

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25 Magazine.
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27 " Foundry.
28 " Machine Shop and Boiler House.
29 Iron Foundry.
30 Coal Shed.
31 Rocket Press House.
32 Acid House.
33 Stables.
34 Gun Carriage Shop.

35 Sulphur House.
36 Ordnance Foundry.
37 Timber Shed.
38 Saw Mill and Joiner Shop.
41 Machine Shop.
42 Erecting "
43 Smithery and Galley Shop.
44 Boiler Shop.
45 Chain "
46 Anchor, Faggoting and Forge Shops
47 " " " " "
48 Boat House.
50 Ship "
51 Timber Shed and Mould Loft.
53 Iron Foundry.
54 Naval Store.
55 Fire Engine House.
56 Provisions and Clothing Store.
57 Rigging Loft and Iron Store.
58 Copper Rolling Mill.
59 Brass Foundry and Finishing Shop.
60 Caboose and Tin Shop.
61 Coppersmith's Shop.
62 Paint "
63 Ship House and Marine Railway.
65 Experimental Battery.
67 Ammunition Store.
68 Office.
70 Pitch House.
74 Watch Box.
79 Boiler House and Chimney.
81 Naval Store.
83 Saw Mill, Boiler Room and Stack.
87 Boiler Room and Stack.
94 West Gate.
95 East "
96 Watch Box.
99 Boat Sheds.

The depth of water, expressed in feet (Plate LXXVIII.), is sufficient for all purposes of transportation of material and finished products to and from the factory.

The site is naturally secure from an attack by a foreign fleet. Its lines of communication with the principal sources of supply seem well secured against destruction by an enemy.

At moderate expense, a junction can be made with the Pennsylvania Railroad, which is close to the yard, and is in direct communication with those steel works that would probably undertake to provide the material for fabrication.

The compass and diversity of skilled labor are limited; but this is not a most important requisite, since the majority of successful manufactories producing steel guns and other ordnance material have been established in localities almost destitute of the skilled labor required for their development.

There is no demand for the site for mercantile purposes and there are no private works near enough to absorb it. While, therefore, it is free from encroachment, the yard is in a most fitting situation for expansion. The climate is favorable.

The fabricated ordnance can be readily transferred to the Annapolis polygon, or to the Sandy Hook proving-ground, for the Pennsylvania Railroad Company, at present, has facilities for transporting a gun of 80-tons weight, and will no doubt meet any demand for transportation

as rapidly as a gun-factory plant can be developed. In fact, in the problem of providing steel for guns and establishing steel gun factories, the question of *transportation* can be easily solved.

The location of a gun factory in the District of Columbia, the representative site of all sections of the country, will combine all local interests; the development and interesting work will be directly under the eyes of those who will be asked to make appropriations for its support; and the proximity of the establishment to the Departments will facilitate supervision.

It would seem, therefore, that, in the selection of the Washington Navy Yard as a site for the Naval gun-factory, the Board has made a most suitable choice.

The Report of the Gun Foundry Board appears to have fully met the requirements of the act of Congress of March 3, 1883, and contains direct information as to the best method to be adopted to provide a means of supplying modern ordnance, and the cost of the buildings and implements to be used in the manufacture thereof. The conclusions are based upon the valuable experience of those who have carefully studied and practised, whose governments have provided generously, that their servants could best meet the demand.

The establishment of a government steel foundry does not appear to be advisable. It would be a step backward. Many years of experiment would be required before this foundry could arrive at the position now held by one or two, at least, of our leading steel manufacturers, whose plants are deficient only in forging apparatus.

The plan, that the Government should provide a hammer for the use of private individuals, is not only very objectionable on account of the reasons set forth by the Chief of Naval Ordnance (page 549), but it divides responsibility, savors of partnership—*so prominently disapproved*—and the expense of transferring the hammer, as suggested, would make the price of the forging instrument enormous, by the addition of the cost of a new foundation.

The objections to the partnership advocated in the views and plans of the Chief of Ordnance, War Department (page 556), are fully discussed in the report, and concisely presented in the conclusion that "*all history warns against such a course.*"

No aid should be given to any corporation that is not based solely upon "price paid for material after passing the required tests."

The danger of failure is even greater with a partnership between the

Government and a private firm than from the conservatism and narrowness of a purely governmental establishment. Both should be avoided.

The Board has indicated an efficient, practical system, whereby the private industries will be developed in providing the material, and the necessary governmental supervision will be retained in the fabrication of the guns. It has shown whence the best implements can be supplied, the time necessary to manufacture them, their cost, and the guaranty of their efficiency. It has pointed out the steel manufacturers of the United States who are willing to undertake the development of plant for the supply of material, if the Government will guarantee employment.

But Congress alone can meet the only remaining, but most important, requisite—an adequate appropriation.

In the estimates for gun factories, and the recommendation that they shall be governmental, Congress can take no just exception to the conclusions of the Board, for the estimates are reasonable, and the gun factory work, that is, machining and assembling the parts and finishing and sighting the guns, is appropriately governmental; even in private establishments where guns are fabricated, the operations are conducted under the supervision and inspection of army and navy officers.

For the purchase of material from the steel manufacturers of the United States, a large appropriation should be made, to be expended under the authority of the President. This appropriation should be made immediately, that the steel manufacturers, who will undertake the supply, may complete a forging-plant in time to meet the demands of the gun factories for material.

With adequate appropriations, to be expended under the direction of an advisory board, confirmed by the Senate; with the understanding that the remuneration of the steel manufacturers shall "be derived solely from the price paid by the Government for the material after passing the tests required"; and with the establishment of the two gun factories, as recommended by the Gun Foundry Board, the United States will no longer be destitute of a means of providing proper ordnance for modern warfare, but will see her private industries producing the best gun and armor material in the world, her gun factories equal to every demand made upon them, and her guns *again* "the models for imitation, and the standards for comparison of all nations."

INDEX.

INDEX OF ILLUSTRATIONS.

NAVAL INSTITUTE PRIZE ESSAY, 1885.

A Prize of one hundred dollars and a gold medal is offered by the Naval Institute for the best Essay presented, subject to the following rules:

1. Competition for the Prize is open to all members, Regular, Life, Honorary and Associate, and to all persons entitled to become members, provided such membership be completed before the submission of the Essay. Members whose dues are two years in arrears are not eligible to compete for the Prize until their dues are paid.

2. Each competitor to send his essay in a sealed envelope to the Secretary on or before January 1, 1885. The name of the writer shall not be given in this envelope, but instead thereof a motto. Accompanying the essay a separate sealed envelope will be sent to the Secretary, with the motto on the outside and writer's name and motto inside. This envelope is not to be opened until after the decision of the Judges.

3. The Judges to be three gentlemen of eminent professional attainments (to be selected by the Executive Committee), who will be requested to designate the essay, if any, worthy of the Prize, and, also, those deserving honorable mention, in the order of their merit.

4. The successful essay to be published in the Proceedings of the Institute, and the essays of other competitors, receiving honorable mention, to be published also, at the discretion of the Executive Committee.

5. Any essay not having received honorable mention, to be published only with the consent of the author.

6. The subject for the Prize Essay is, "*Inducements for retaining trained seamen in the Navy, and best system of rewards for long and faithful service.*"

7. The Essay is limited to forty-eight printed pages of the "Proceedings ot the Institute."

8. The successful competitor will be made a Life Member of the Institute.

9. In the event of the Prize being awarded to the winner of a previous year, a gold clasp, suitably engraved, will be given in lieu of a gold medal.

CHAS. M. THOMAS,
Secretary.

ANNAPOLIS, MD., *April* 3, 1884.

1885.

PROCEEDINGS

OF THE

UNITED STATES

NAVAL INSTITUTE.

VOLUME XI.

PUBLISHED QUARTERLY BY THE INSTITUTE.

ANNAPOLIS, MD.

PRESS OF ISAAC FRIEDENWALD
BALTIMORE, MD.

CONTENTS.

APPENDIX.

No. 32.